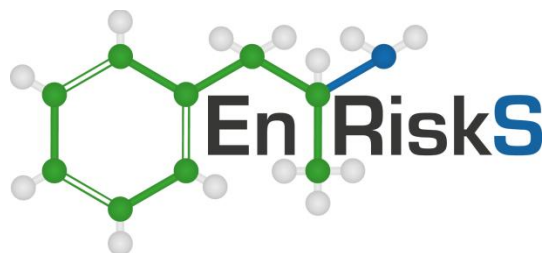


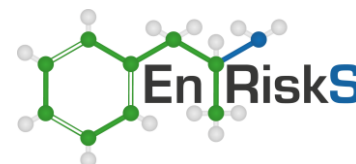


Human Health Risk Assessment: Respirable Crystalline Silica from the Proposed Strathmore Quarry

Prepared for: Quarry Plan NSW on behalf of Oats Block Pty Ltd

3 March 2026





Document History and Status

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Limitations

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It is prepared in accordance with the scope of work and for the purpose outlined in the **Section 1** of this report.

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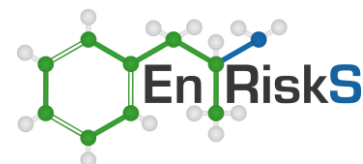
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Glossary of terms

ACGIH	American Conference of Governmental Industrial Hygienists.
AIOH	Australian Institute of Occupational Hygienists Inc
ANZECC	Australia and New Zealand Environment and Conservation Council
AQIA	Air Quality Impact Assessment
ATSDR	US Agency for Toxic Substances and Disease Registry
COPD	Chronic Obstructive Pulmonary Disease
EIS	Environmental Impact Statement
ESL	Effects Screening Levels
HHRA	Human Health Risk Assessment
HQ	Hazard Quotient
IARC	International Agency for Research on Cancer
MDH	Minnesota Department of Health
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
NIOSH	National Institute for Occupational Safety and Health
NOAEL	No Observable Adverse Effect Level
OEHHA	California EPA Office for Environmental Health Hazard Assessment
PEL	Permissible Exposure Limit
PM _{2.5}	Particulate matter below 2.5 µm in diameter
PM ₁₀	Particulate matter below 10 microns in diameter
REL	Recommended Exposure Limit
ReV	Chronic Reference Value
RCS	Respirable Crystalline Silica
RfC	Reference Concentration
TC	Tolerable Concentration
TCEQ	Texas Commission on Environmental Quality
TDI	Tolerable Daily Intake
TLV	Threshold Limit Value
TRV	Toxicity Reference Value
TSP	Total Suspended Particulates
TWA	Time-weighted Average
UR	Unit Risk
USEPA	United States Environmental Protection Agency,
WHO	World Health Organisation

Executive summary

Introduction

Environmental Risk Sciences Pty Ltd (enRiskS) has been engaged by Quarry Plan NSW, on behalf of Oats Block Pty Ltd, to undertake a human health risk assessment (HHRA) in relation to potential exposures to respirable crystalline silica (RCS) from the proposed Strathmore Quarry (the “project”).

The project is a proposed hard rock (mudstone) quarry located at 51 Gowrie Road, near Warral, approximately 8.8 km to the southwest of Tamworth, NSW. It is proposed that the project will extract up to 240,000 tonnes per annum and ship up to 1,600 tonnes per day of mudstone, for up to 30 years. The surrounding area is primarily used for agricultural purposes (quarries, grazing, cropping and associated rural dwellings). The residential area of Kingswood is located approximately 550 m to the north-east of the proposal site.

An Environmental Impact Statement (EIS) was completed for the project in 2024 with the EIS on public exhibition between 11 November 2024 and 9 December 2024. The EIS addressed a range of matters as required in the Department of Planning and Environment Secretary’s Environmental Assessment Requirements (SEARS) issued on 3 July 2023. This includes an Air Quality Impact Assessment (AQIA), completed by Northstar (dated 27 March 2024).

Public submissions in relation to the project raised concerns about community exposure to RCS. The project is in a largely rural area, with more dense suburban development located at Kingswood. The Northern Regional Planning Panel has deferred the hearing of the project application until a HHRA has been completed in relation to RCS from the project.

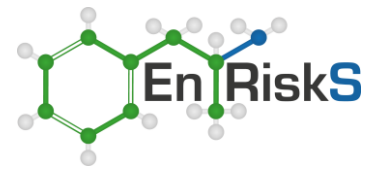
This report provides a review and detailed assessment of the potential risks to the health of the community posed by the potential presence of RCS in dust emitted from the project.

Objectives

The overall objectives of the assessment presented in this report is to assess potential risks to the health of the community posed by the potential presence of RCS in dust emitted from the project.

This assessment has been undertaken to evaluate potential risks to human health at residential properties nearby to the project, based on the data and information available to 2 March 2026. The HHRA has addressed human health risk issues relevant to RCS that may be present in dust sourced from the project and the ongoing low-density rural/residential use of the nearby properties.

The assessment has not addressed any ecological risk issues, human health risk issues associated with other chemicals or any occupational health and safety issues relevant to the project. No assessment has been undertaken of other non-site sourced contamination that may be present beneath off-site properties.



Summary and conclusions

Exposures that are of most concern in relation to silica, relate to the inhalation of RCS. RCS refers to the presence of silica in fine dust particles that are small enough to be inhaled and penetrate deep into the lungs – i.e. $PM_{2.5}$. The crystalline shape of these fine particles has the potential to result in inflammation and the development of disease (including silicosis and lung cancer) where exposure occurs over a long period of time.

There are significant health effects that have been identified in relation to occupational exposures to RCS. The available data is limited in relation to supporting that these health effects may occur within the community, where exposures are significantly lower than within occupational environments. Regardless, guidelines are available in relation to the assessment of community exposure to RCS. These guidelines relate to long-term exposures to RCS in air as $PM_{2.5}$. The guideline adopted in this HHRA is $3 \mu g/m^3$. The guideline is for exposures by the community from all sources, including background concentrations of RCS in the environment.

Northstar (2024) outlines air dispersion modelling that was completed to estimate concentrations of $PM_{2.5}$ in air at the local community (sensitive receptors R1 to R10) during project construction and operations. The modelled annual average incremental impact from the project (the annual average concentrations of $PM_{2.5}$ predicted to be sourced from the project) have been considered in this HHRA. This HHRA has assumed that these concentrations are 100% RCS, as well as 43% RCS, the latter being the reported free silica content in one sample of mudstone from the project area.

The AQIA indicates that the predicted annual average incremental $PM_{2.5}$ concentration at sensitive receptors R1 to R10 is $<0.1 \mu g/m^3$. Hence, the project is not predicted to increase RCS as $PM_{2.5}$ above the background level ($1.9 \mu g/m^3$). Total predicted exposures to RCS remain below the adopted screening level guideline of $3 \mu g/m^3$.

The AQIA indicates that the higher incremental PM concentrations are primarily due to the use of the site access road. Watering of the road is recommended in the AQIA, where visible dust is observed. This will reduce predicted $PM_{2.5}$ concentrations, further increasing the margin of safety in the HHRA.

Consideration of uncertainties present in the HHRA does not change HHRA outcomes.

On this basis, there are no health risk issues of concern in relation to long-term exposures to RCS in air within the community surrounding the project.

Section 1. Background

1.1 Introduction

Environmental Risk Sciences Pty Ltd (enRiskS) has been engaged by Quarry Plan NSW, on behalf of Oats Block Pty Ltd, to undertake a human health risk assessment (HHRA) in relation to potential exposures to respirable crystalline silica (RCS) from the proposed Strathmore Quarry (the “project”).

The project is a proposed hard rock (mudstone) quarry located at 51 Gowrie Road, near Warral, approximately 8.8 km to the southwest of Tamworth, NSW. It is proposed that the project will extract up to 240,000 tonnes per annum and ship up to 1,600 tonnes per day of mudstone, for up to 30 years. The surrounding area is primarily used for agricultural purposes (quarries, grazing, cropping and associated rural dwellings). The residential area of Kingswood is located approximately 550 m to the north-east of the proposal site.

An Environmental Impact Statement (EIS) was completed for the project in 2024 with the EIS on public exhibition between 11 November 2024 and 9 December 2024. The EIS addressed a range of matters as required in the Department of Planning and Environment Secretary’s Environmental Assessment Requirements (SEARS) issued on 3 July 2023. This includes an Air Quality Impact Assessment (AQIA), completed by Northstar (dated 27 March 2024).

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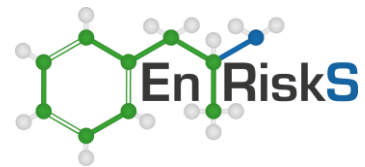
This report provides a review and detailed assessment of the potential risks to the health of the community posed by the potential presence of RCS in dust emitted from the project.

1.2 Objectives and scope of works

The overall objectives of the assessment presented in this report is to assess potential risks to the health of the community posed by the potential presence of RCS in dust emitted from the project.

More specifically this assessment has undertaken the following:

- review the information provided in the EIS in relation to the project, including the Northstar (2024) AQIA (completed for the EIS)
- review available information in relation to the composition of rock proposed to be quarried, in relation to the percentage of silica
- characterise the community surrounding the project, particularly in relation to existing respiratory health
- review the current literature relevant to the assessment of non-occupational exposures to RCS
- provide an assessment of potential risks to community health from exposure to RCS derived from the operation of the project
- where relevant, provide any recommendations for the mitigation of impacts.



This assessment has been undertaken to evaluate potential risks to human health at residential properties nearby to the project, based on the data and information available to 2 March 2026, and as described in **Section 2**. The HHRA has addressed human health risk issues relevant to RCS that may be present in dust sourced from the project and the ongoing low-density rural/residential use of the nearby properties.

The assessment has not addressed any ecological risk issues, human health risk issues associated with other chemicals or any occupational health and safety issues relevant to the project. No assessment has been undertaken of other non-site sourced contamination that may be present beneath off-site properties.

1.3 Methodology

In general, the approach taken for the assessment of human health and environmental risks is in accordance with guidelines/protocols endorsed by Australian regulators, including:

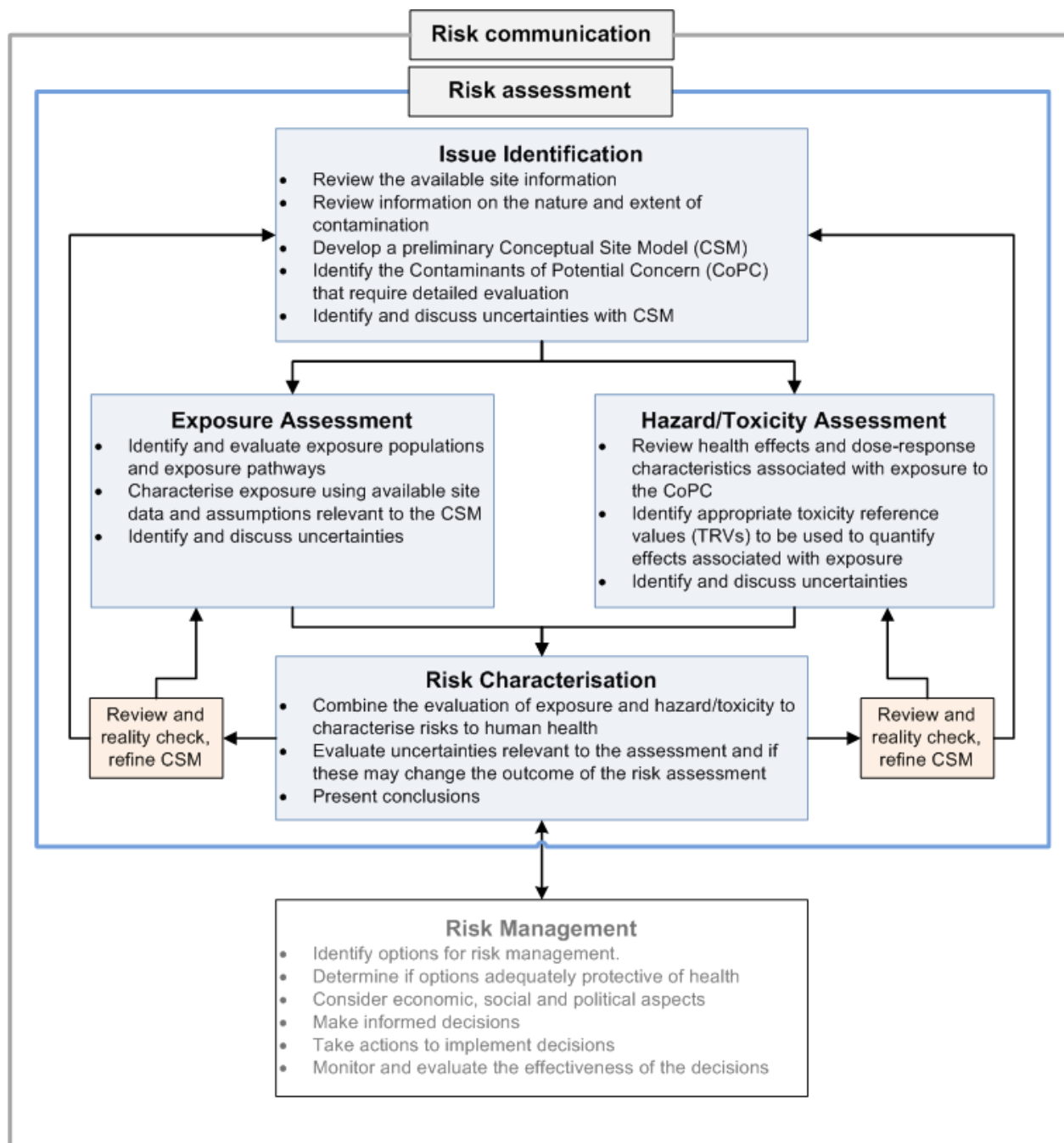
- enHealth Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards (enHealth 2012a).
- enHealth Australian Exposure Factor Guide (enHealth 2012b).
- National Environmental Protection Measure – Assessment of Site Contamination (ASC NEPM) including Schedule B1 Guideline on Investigation Levels of Soil and Groundwater (NEPC 1999 amended 2013a) and Schedule B4 Guideline on Health Risk Assessment Methodology (NEPC 1999 amended 2013b).

In addition, protocols and guidelines developed by international agencies such as the United States Environmental Protection Agency (USEPA) and the World Health Organisation (WHO) have been used (and referenced) to provide supplementary guidance where required. International guidance has not been adopted where it is inconsistent with the Australian regulatory or policy setting.

The overall approach adopted in this assessment is as follows:

- present information on the assessment of dust and respirable fractions, and the toxicity of RCS particularly in relation to community exposures (**Section 2**)
- review the available data that characterise potential community exposures to RCS in dust from the project (**Section 3**)
- based on the above, assess potential community exposures and health risks to RCS from the project (**Section 4**).

The overall approach for the HHRA is outlined in the following (modified from enHealth 2012):



Section 2. Dust and RCS

2.1 General

This section presents an overview of the key properties of dust/particulate matter (PM) that are relevant when evaluating health impacts, and the current understanding of the toxicity of RCS (which is part of PM).

2.2 Background on particulate matter

2.2.1 Overview

Dust/PM is a widespread air pollutant (that has and will always be present in air) with a mixture of physical and chemical characteristics that vary by location (and source). Unlike many other pollutants, particulates comprise a broad class of diverse materials and substances, with varying morphological, chemical, physical and thermodynamic properties, with sizes that vary from <0.005 micrometres (μm) to >100 μm . Particulates can be derived from natural sources such as crustal dust (soil), pollen and moulds, and other sources that include combustion and industrial processes. Secondary particulate matter is formed via atmospheric reactions of primary gaseous emissions. The gases that are the most significant contributors to formation of secondary particulates include: nitrogen oxides, ammonia, sulfur oxides, and certain organic gases (derived from vehicle exhaust; combustion sources; and agricultural, industrial and biogenic emissions).

The potential for particulate matter to result in adverse health effects is dependent on the size and composition of the particulate matter.

2.2.2 Particle size

The size of particulates is important as it determines how far from an emission source the particulates may be present in air (with larger particulates settling out close to the source and smaller particles remaining airborne for greater distances) and also the potential for adverse effects to occur as a result of exposure (how far the particles can infiltrate into the respiratory system).

Only particulates that are small enough can penetrate the lungs where there is the potential for effects to occur. If the particles are too large then will be captured high up in the respiratory tract, trapped and flushed out and eventually swallowed.

Dust is commonly assessed based on four types (or groups of) of particles: $\text{PM}_{2.5}$, PM_{10} , total suspended particulates (TSP) and deposited dust.

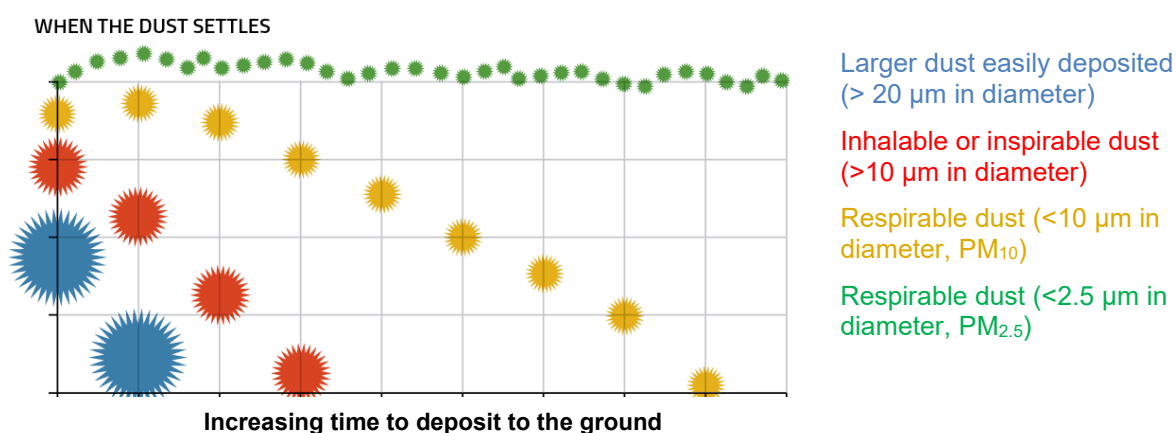
Deposited dust includes particles of any size, but it generally comprises large size dust particles, i.e. greater than 20 microns in diameter¹. These particles are too large to reach the lungs and are not considered to be of concern in relation to exposure. These particles have enough mass that they easily fall out of the air and deposit or accumulate on surfaces. These larger particles fall out and deposit onto surfaces close to specific sources, such as quarry activities. Sometimes sufficient dust can deposit so that it results in a visible layer of dust, which often considered to be a nuisance.

¹ The size, diameter, of dust particles is measured in micrometers (microns).

TSP refers to all particulates with an equivalent aerodynamic particle² size below 50 microns (μm ; also known as micrometers) in diameter. It is a gross indicator of the presence of dust with a wide range of sizes:

- Larger particles termed 'inspirable', comprise particles around 10 μm and larger, are more of a nuisance as they will deposit out of the air (measured as deposited dust) close to the source and, if inhaled, are mostly trapped in the upper respiratory system³ and do not reach the lungs. This is the same with the even larger particles in deposited dust.
- Finer particles smaller than 10 μm , termed 'respirable', are transported further from the source and are of more concern with respect to human health as these particles can penetrate the lungs (see discussion below).

The deposition of dust based on the different particle sizes is illustrated below:



The focus of any assessment addressing potential health effects from PM relates to particulates of a size that are respirable. These particulates comprise the following (as illustrated in **Figure 2.1**):

- PM_{10} – particulate matter below 10 μm in diameter.
- $\text{PM}_{2.5}$ – particulate matter below 2.5 μm in diameter.
- PM_1 – particulate matter below one μm in diameter, often termed very fine particles.
- Ultrafines – particulate matter below 0.1 μm in diameter.

These particles are small and have the potential to penetrate beyond the body's natural clearance mechanisms of cilia and mucous in the nose and upper respiratory system, with smaller particles able to further penetrate the lower respiratory tract⁴ and lungs. Once in the lungs, adverse health

² The term equivalent aerodynamic particle is used to reference the particle to a particle of spherical shape and particle of density one gram per cubic metre.

³ The upper respiratory tract comprises the mouth, nose, throat and trachea. Larger particles are mostly trapped by the cilia and mucosa and swept to the back of the throat and swallowed.

⁴ The lower respiratory tract comprises the smaller bronchioles and alveoli, the area of the lungs where gaseous exchange takes place. The alveoli have a very large surface area and absorption of gases occurs rapidly with subsequent transport to the blood and the rest of the body. Small particles can reach these areas, be dissolved by fluids and absorbed.

effects may occur that include mortality and morbidity, which have been causally linked with a range of adverse cardiovascular and respiratory effects (USEPA 2019).

Figure 2.1 provides a general illustration to provide some context in relation to the size of different particles (discussed above) and relevance/importance for the assessment of inhalation exposures.

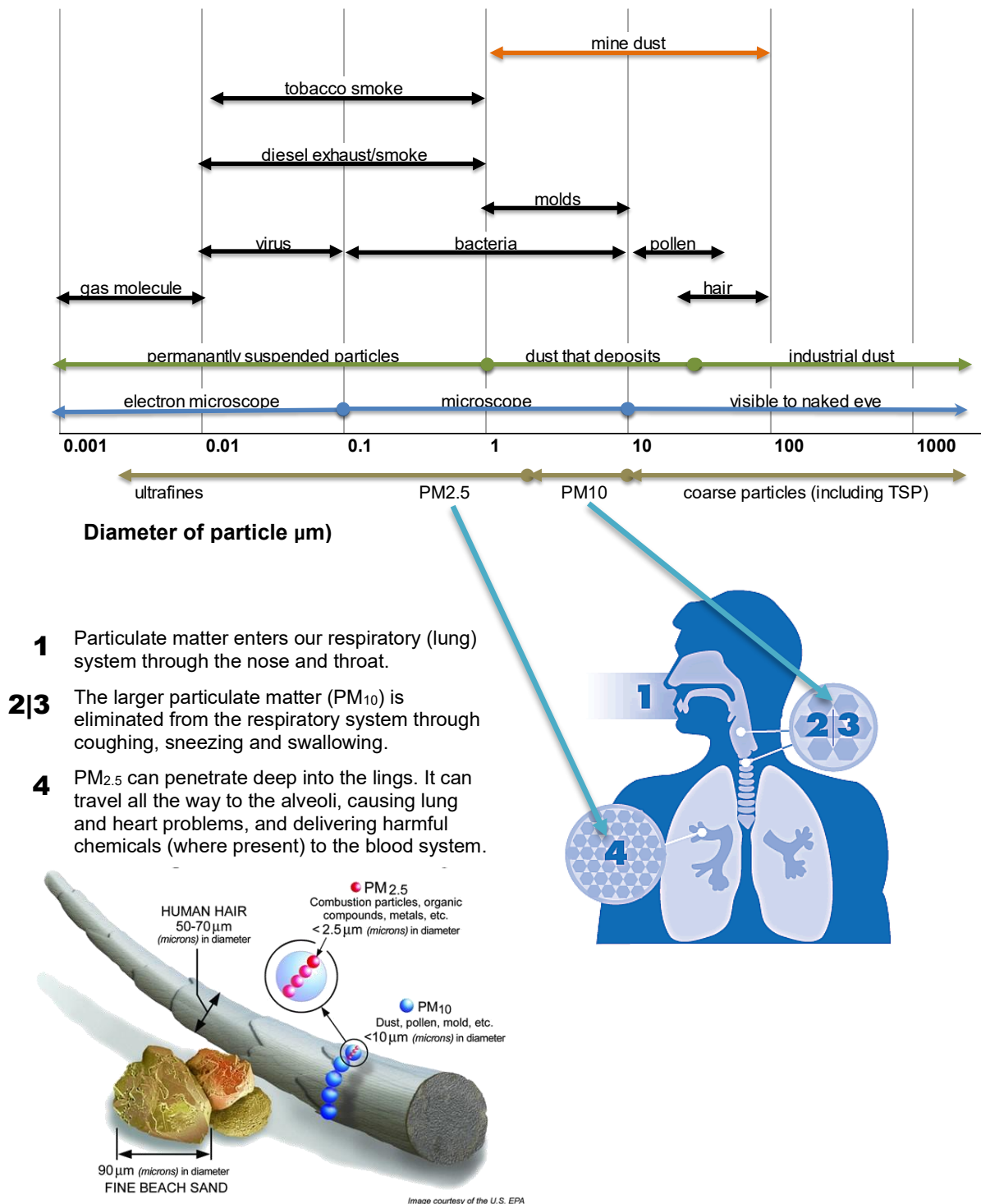


Figure 2.1: Illustrative representation of relative particle sizes and importance for health

In relation to measuring and assessing PM, the following should be noted:

- The measurement of PM in air most commonly reports PM₁₀. This is the concentration of PM that less than or equal to 10 µm in diameter (and includes the smaller fractions of PM_{2.5}, PM₁ and ultrafines). The measurement techniques for PM₁₀ are well established and provide stable, robust, verifiable data that is consistently reported across all regions and countries.
- The measurement of PM_{2.5} is becoming more common. This is the concentration of PM that less than or equal to 2.5 µm in diameter (and includes the smaller fractions of very fine particles and ultrafines). The measurement techniques used for PM_{2.5} are less well-established resulting in data that varies depending on the type of equipment used and how it is set-up and maintained. Data on this fraction is, however, of most relevance to the assessment of health impacts.
- The measurement of very fine particles and ultrafine particles is difficult (using equipment that is less robust/stable and provides variable data) and has not been undertaken in most air environments. In addition, there are no health-based guidelines established for these fine fractions of particles. Hence the assessment of these fractions is not undertaken where specific sources of particles is being considered.

Figure 2.1 shows that PM_{2.5} and smaller is the particle size that may reach the lower parts of the respiratory tract (the smaller bronchioles and alveoli). This is the area of the lungs where gaseous exchange takes place and the area that may be impacted by fine particles that have specific characteristics including RCS (refer to **Section 2.3**).

Figure 2.1 also illustrates that particle sizes generated during mining operations, including quarry operations, principally comprise sizes between 1 and 100 µm in diameter, with most of the dust considered coarse particles (comprising deposited dust and TSP), PM₁₀ and some PM_{2.5}. This contrasts with urban areas where PM is dominated by vehicle emissions and smoke (from woodfired heaters) which are dominated by PM_{2.5} and smaller particles.

2.2.3 Particle composition

Particle composition describes the makeup (chemical composition) and/or shape of the dust particle that has the potential to result in health effects, if inhaled and where the particle is small enough to penetrate the lungs. This is particularly important when discussing exposures to RCS as the health effects specific to these particles is linked to the crystalline nature, specifically the hardness of the particles and the crystal fragmentation (i.e. shape) which ultimately results in an inflammatory response (Turci et al. 2016) (refer to the detailed discussion in **Section 2.3**).

Hence when reviewing the available information, it is important to understand the concentration of particulates in air, specifically PM_{2.5}, as well as the proportion of the dust that is comprised of RCS.

2.3 Toxicity of RCS

2.3.1 General

The toxicity of RCS has been evaluated following guidance provided by enHealth (enHealth 2012a) and NEPM (NEPC 1999 amended 2013b). This requires consideration of the health endpoints and where carcinogenicity is identified, an understanding of the mechanism of action. A detailed review of the available information and data is provided in **Appendix A**. This section presents an overview of the key aspects relating to the toxicity of RCS and the approach that has been adopted for the assessment of community exposures.

Silica in the form of quartz is one of the most commonly occurring minerals on the Earth's surface, with over 95% of the earth's crust made of minerals containing silica. There are two forms of silica – crystalline silica and amorphous silica. Amorphous silica lacks a crystalline structure and is not further assessed. Two common forms of crystalline silica are quartz and cristobalite.

Silica from quartz is an odourless, white, black, purple or green solid and is generally considered to be insoluble in water and unreactive in the environment. RCS in dust is also considered stable.

Silica is naturally released into the environment through the weathering of rocks, volcanic activity and biogenic sources. Hence, background exposures (i.e. naturally occurring exposures outdoors or indoors – where there are no specific silica sources) may occur through air, indoor dust, food, water, soil and various consumer products. Crystalline silica has a wide variety of commercial and industrial uses including:

- to produce high-temperature or refractory silica brick, foundry moulds and cores for metal casings
- to manufacture glass and pure silicon for computer chips
- as a filler in asphalt, plastics, rubber and paint
- as an abrasive (e.g. for blasting)
- in sand and gravel used for building roads and in concrete
- in the water-sand mix used by the oil and gas industry to fracture rock
- in bricks, mortar, plaster, calk, roofing granules and stone building materials (including benchtops)
- in art clay, glazes and gemstones in jewellery
- in personal care products such as cleansers and talcum powder and cosmetics
- in pet litter and furniture foam.

Given the wide range of sources of silica in the environment, it is expected that there would be RCS in urban and rural environments. Review of information related to background or ambient levels of RCS in air from the available Australian and international sources is presented in **Appendix A**. Based on the available data a conservative (i.e. upper estimate) of RCS in ambient air (background) is expected to be around 1.9 µg/m³.

2.3.2 Exposure, absorption and health effects

General

The exposure route of concern for RCS is inhalation. Exposure to RCS is known to occur in industrial and occupational settings, with RCS recognised as an important occupational inhalation hazard.

When RCS is inhaled it is the fine fractions that are of importance as these are small enough to penetrate the lungs (refer to **Figure 2.1**) where they can be deposited. RCS particles are not soluble, so they are not easily absorbed by the body and remain as solid particles once deposited in the lungs.

The presence of these particles in the lungs damages cells in the lungs, which impairs the ability of the lungs to clear or flush out the particles (which would normally occur through mucous or coughing). Hence these particles can become “stuck” or embedded in the lungs. As these particles can remain in the lungs for a long period of time the shape of the particles becomes important as this leads to inflammation which results in disease such as silicosis or fibrosis. The prolonged inflammation results in the formation of fibrotic scar tissue and degradation of the lung clearance mechanism. The improper repair of damaged lung tissue is essential for the development of chronic disease.

Acute exposures can also result in respiratory inflammation which stimulates a significant increase in alveolar macrophages, leading to elevated levels of reactive oxygen species (ROS), which plays an important part in inflammation and the production of antioxidant compounds

Health effects associated with occupational exposures include silicosis, lung cancer, renal toxicity and autoimmune diseases. The health effects that are generally of greatest concern to humans are silicosis and lung cancer.

Silicosis is a progressive and irreversible fibrotic lung disease that has been recognised since Roman and Greek times and is not caused by any substance other than RCS (including amorphous silica). A fibrotic lung disease is a disease where excess fibrous connective tissue is formed in an organ. This type of effect is also referred to as scarring when in response to an injury. Silicosis is caused by inhaling RCS, where the RCS is then deposited on the lungs. There is no known cure for silicosis. There are several types of silicosis:

- **Acute silicosis** is caused by intense exposure to fine RCS dust, such as those generated during blasting or tunnelling. With this disease, the alveolar (the tiny air sacks in the lungs which absorb oxygen) fill with a protein rich fluid containing damaged cells. Inflammation of the lung also occurs. Symptoms include laboured breathing, dry cough, decreased pulmonary function, fever and fatigue followed by cyanosis and respiratory failure.
- **Simple silicosis** is the most common type of silicosis and results from long periods (10 to >20 years) of continuous exposures to relatively low levels of RCS dust. Primary function and general health is typically not compromised in the early stages, however, intensity of cough and mucous discharge increases as the disease progresses. Decreases in lung function are often observed (including non-reversible air flow obstruction).

- **Progressive massive fibrosis (PMF)** is a progression of simple silicosis where nodular lung lesions (injuries) grow and come together to form masses of connective tissue that ultimately destroys the lung structures including the blood vessels. This leads to restricted lung volume and poor gas exchange.
- **Accelerated silicosis** is a progressive form of simple silicosis that develops 5 to 10 years after exposure and is typically associated with moderate exposures (as opposed to simple silicosis which is associated with lower level exposures). Symptoms are similar to those of simple silicosis.

Decreased lung function can also be observed in the absence of silicosis and may be caused by exposures to RCS. This is known as chronic obstructive pulmonary disease (COPD). COPD is characterised by limitation in airflow caused by chronic bronchitis, emphysema, asthma or peripheral airways disease (ATSDR 2019; NIOSH 2002). Cigarette smoking is the main cause of COPD however occupational exposures to dust and community air pollution can also contribute and there are limited studies that link RCS and COPD. No studies have investigated a potential link between RCS and asthma and RCS is not known to cause asthma occupationally.

The most important factor for the development of silicosis is cumulative exposure to RCS. Time from first exposure to onset of symptoms can vary from a few weeks (for acute silicosis) to 20 years or more (for simple silicosis). Disease severity may also slowly increase following cessation of exposure, where RCS is retained in the lungs.

Carcinogenicity

Several studies have looked at whether exposure to RCS causes lung cancer and compared to other occupational lung carcinogens, the reported association is low. However, an increase risk to lung cancer in RCS workers has been reported, with risks dependant on cumulative (successive and ongoing) exposures over times. RCS workers are workers who are frequently exposed to crystalline silica at high levels as part of their occupation/work. This relates to workers being in frequent proximity to or undertaking activities such as the crushing, cutting, drilling, grinding, sawing and polishing of stone or man-made products that contain silica⁵.

Inhaled crystalline silica dust in the former of quartz or cristobalite, is classified as Group 1 (carcinogenic to humans) by the International Agency for Research on Cancer (IARC) (IARC 2012), based on occupational data. TCEQ (TCEQ 2009) also emphasises that the identification of RCS as carcinogenic relates only to occupational exposures. The mechanism for carcinogenicity is likely to be inflammation.

The classification of RCS as an occupational carcinogen is supported by ACGIH (2010). The ACGIH review identified that there was a consensus among US and international agencies is that there is a positive association between occupational silica exposures and lung cancer. Most agencies consider that silica does not directly act to initiate cancer, however, do agree that workers that have pulmonary fibrosis (following exposure to silica) are at risk of developing lung cancer (but

⁵ Refer to additional information available from SafeWork Australia in relation to work activities that represent a high risk exposure <https://www.safeworkaustralia.gov.au/silica>

does not prove that the fibrosis leads directly to lung cancer). However, ACGIH considers that a reduction in worker exposures such that risks from silicosis are eliminated will likely protect against the formation of lung cancer.

The available evidence indicates that RCS is genotoxic with the ability to cause mutagenicity and DNA damage (ATSDR 2019).

No information is available in relation to the susceptibility of children to RCS as silicosis is generally considered to be an occupational disease that typically appears after prolonged exposures. The same adverse effects would be expected to appear in children where exposures were like adult workers. Individuals with underlying lung and health conditions such as asthma and emphysema may be more susceptible to adverse respiratory effects from inhaled RCS. The risk of silicosis in workers who smoke cigarettes is also higher than in workers who do not smoke.

2.3.3 Quantitative toxicity reference values

Toxicity reference values (TRVs) are quantitative values that are derived by key health authorities to be protective of the health effects that have been identified for a chemical. This involves an understanding of the different types of health effects that have been identified. It is often the case that different health effects occur at different levels of exposure. The detailed reviews that are undertaken by health authorities identify what the most sensitive health effect is and what would be the lowest, or most protective, quantitative value. This is the TRV, and it is established to be protective of all health effects.

For RCS two types of toxicity values are available (refer to **Appendix A**):

- **Occupational air guidelines:** these guidelines are applicable to individuals who are exposed to chemicals in the workplace through use or handling, that does not present an unacceptable risk to worker health or cause undue discomfort. These guidelines relate exposures by healthy workers in the workplace, during work hours. The guidelines are higher than ambient or community air guidelines and may be at levels that are mildly irritating.
- **Community air guidelines:** these guidelines represent the concentration of a chemical in air that, based on the current science, does not present an unacceptable risk to public or community health. These guidelines are based on a range of different studies conducted in animals and humans (from occupational studies or studies in large populations – epidemiological studies), with the application of an uncertainty factors to make sure that the guideline is relevant to the community who may have a range of sensitivities. The uncertainty factors may also consider any limitations there are with the available studies.

The community air guidelines are the relevant guidelines for consideration in this HHRA.

Based on the available guidelines and information related to the development of these guidelines (refer to **Appendix A**), the following TRV or guideline has been adopted for the assessment of community exposures to RCS:

- RCS in air as PM_{2.5} (based on an annual average concentration) = 3 µg/m³



This guideline is consistent with evaluations undertaken in California (OEHHA 2005), Texas (TCEQ 2009) and Minnesota (MDH 2013), and adopted by the Victorian EPA (EPA Victoria 2007) for the assessment of RCS exposures in the community surrounding mining and extractive industries (which includes quarry activities). The guideline is protective of all health effects for exposures by all members of the community.

Section 3. Review of available information

3.1 General

This section provides a summary of the information relevant to the assessment and characterisation of the potential for RCS impacts within the community. This assessment is based on a review of the following information unless otherwise indicated:

- Information provided in the EIS:
 - Northstar (2024), Strathmore Quarry Project Air Quality Impact Assessment, 51 Gowrie Road, Warral NSW, Northstar Air Quality Pty Ltd, 27 March 2024.
 - Oats Block (2025), Strathmore Quarry Environmental Impact Statement, Oats Block Pty Ltd, 12 August 2025 including Plans 1 to 15.
- Additional information provided by Oats Block Pty Ltd:
 - Scope Geo Petrographic Report dated February 2026.

A copy of the Scope Geo report is provided in **Appendix B**.

Review of the available information has focused on the dust emissions and exposures, as RCS is part of dust. The key community of interest in relation to this review is the residential area of Kingswood, located approximately 550 m to the north-east of the proposal site.

3.2 Project description

The project site is owned by Oats Blocks and is about 325 hectares in area, located about 8.8 km in a south-westerly direction from the Tamworth central business district. The project comprises a mudstone quarry (Strathmore Quarry) which will extract up to 240,000 tonnes per annum and ship up to 1,600 tonnes per day of mudstone, for up to 30 years. The project will supply mudstone rock derived quarry products primarily suitable for fill, as well as road construction and maintenance. The maximum disturbance area is approximately 12 hectares.

The project site is zoned “RU4 Primary Production Small Lots” under Tamworth Regional Local Environmental Plan 2010.

The project site has not been previously quarried. However, the project site has been cleared in conjunction with historical agricultural land use. Some scattered paddock trees remain; ongoing cultivation of crops has effectively removed most native ground cover plants.

Figure 3.1 and **Figure 3.2** shows the project location.

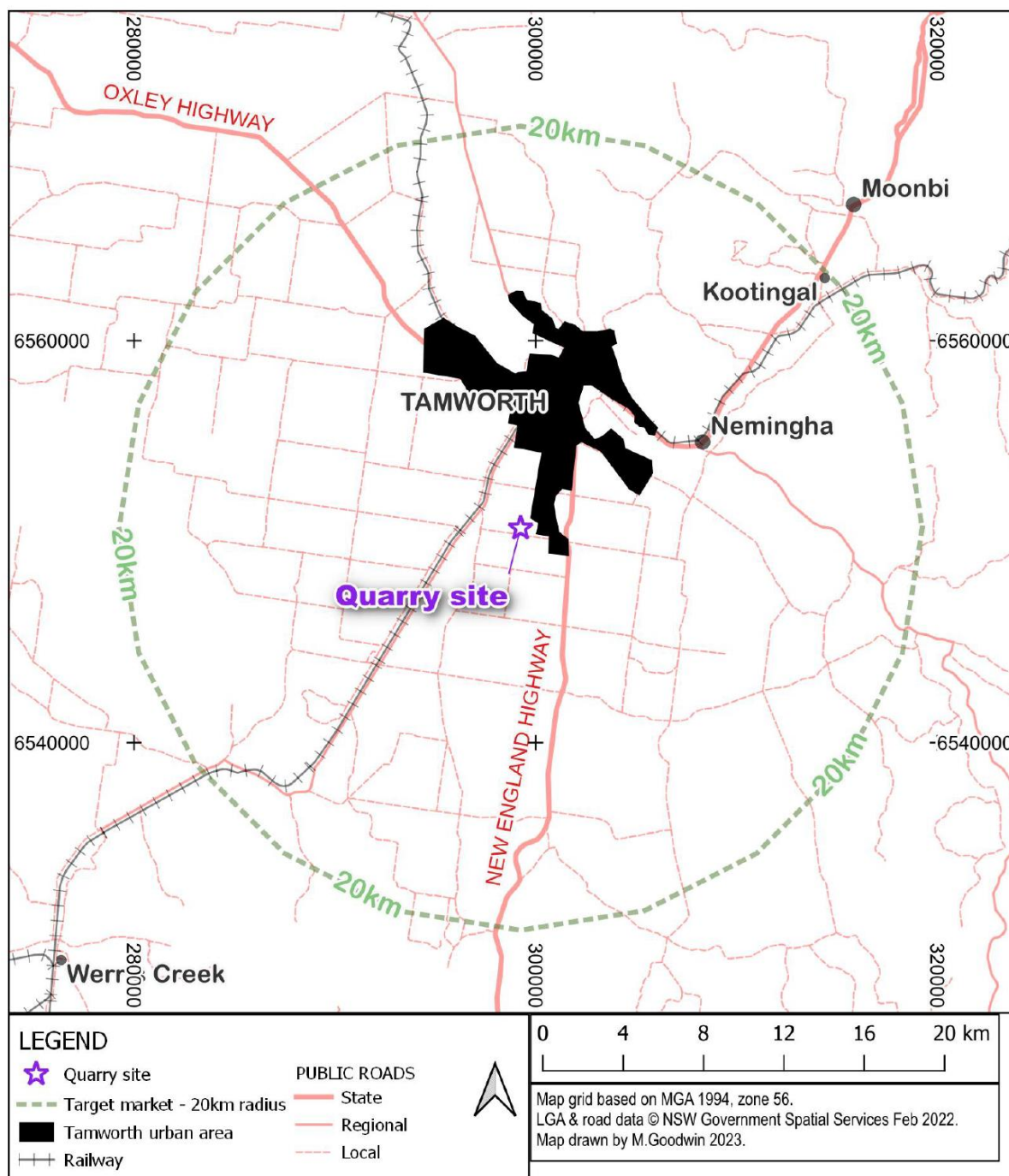


Figure 3.1: Regional project location (Oats Block 2025 EIS)

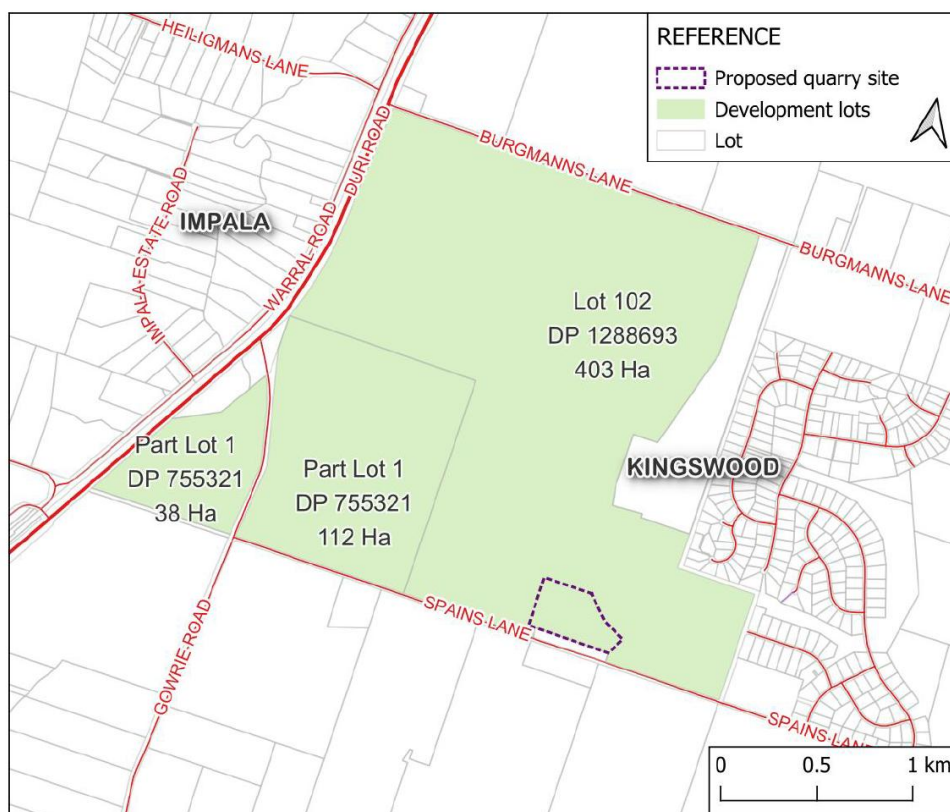


Figure 3.2: Project location – development lots (Oats Block 2025 EIS)

The project will comprise the following:

- extraction area (quarry void)
- processing and stockpile areas
- maintenance and storage areas
- private quarry access track from Gowrie Road
- stormwater retention ponds, primarily in a sump within the project site
- ancillary components including an office, parking, and staff amenities.

It is expected that the project will include construction and two stages (Stage 1 and Stage 2) and include:

- progressive installation of environmental controls e.g. erosion and sediment control measures and berms to mitigate noise and aesthetic impacts
- delineation of the site and stockpiling areas
- construction of fencing
- construction of a site office, weighbridge and car parking area
- crush and screen material at the site to use to construct the access road and intersection
- construction of an access road and intersection with Gowrie Road
- business identification sign
- vegetation clearance, soil stripping and stockpiling for use in landscape mounds
- quarry operations, including crushing, screening and importing materials for blending

- closure and rehabilitation of quarry site.

No blasting, drilling or explosive use is proposed for the project. Material excavation will be undertaken via ripping with an excavator.

The proposed operational hours are 7 am to 6 pm Monday to Friday and 7 am to 2 pm Saturday. No quarrying operations are proposed on Sunday or public holidays.

3.3 Other quarry operations

Two existing quarries are located adjacent or close to the project:

- TfNSW Quarry located adjacent to the south within Lot 1, DP208222
- TRC Quarry located to the south across Spains Lane within Lot 422, DP 1035806.

Both quarries have been operated sporadically for the past 50 odd years.

Figure 3.3 shows the location of the project as well as the 2 existing quarries.

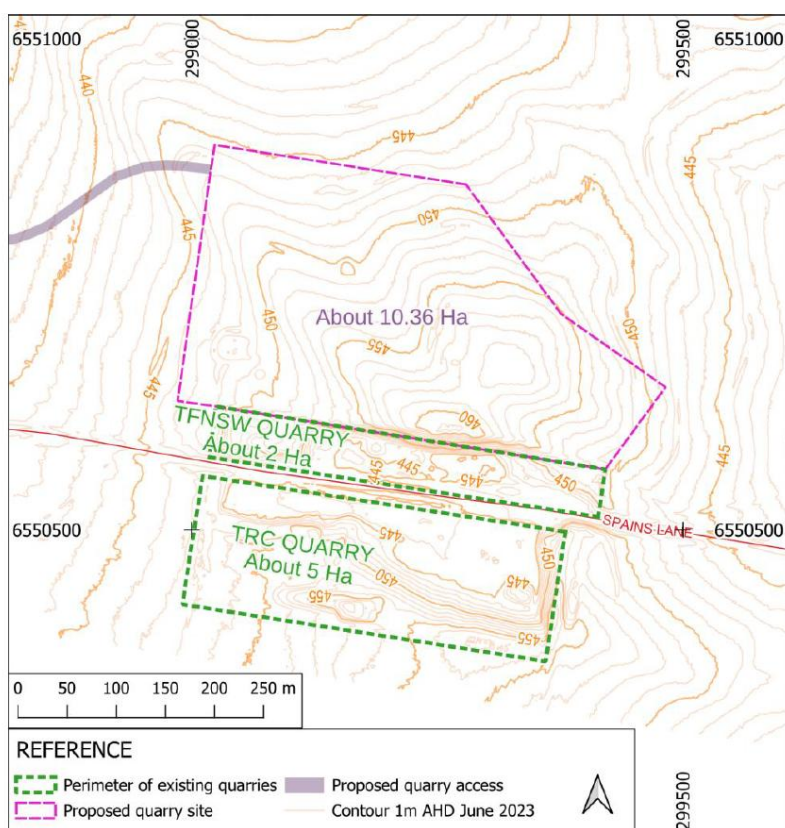


Figure 3.3: Existing quarries in relation to the project (Oats Block 2025 EIS)

Oats Blocks has obtained the lease over the TfNSW quarry and intends to extract mudstone from the from the vicinity of the boundary between this quarry and project. The status of the TRC quarry is unknown.

The potential for cumulative air quality impacts from the proposed and existing quarries is not considered further by Northstar (2024) as:

- peak operations at the different quarries are unlikely to occur simultaneously
- the quarries have different access routes
- the level of conservatism in the AQIA is considered adequate to cover potential short-term impacts associated with operations at more than one quarry.

A desktop search completed by Northstar did not identify any other nearby significant sources of potential air quality impacts.

3.4 Local community

3.4.1 General

The project is in the Tamworth Regional Council local government area (LGA), which has a population of approximately 62,000 people. Tamworth is the largest town and the administrative centre within the LGA. Dominant employment sectors within the LGA are health care, retail, manufacturing, education, construction and agriculture.

The proposal is in an area with a relatively flat topography. Meteorological data is available from the Tamworth Airport BOM station, located approximately 10.8 km away from the proposal. Meteorological data from 2018 to 2022 has been used in the AQIA, where similar wind distribution patterns were reported between years. Most wind speeds experienced at the Tamworth Airport monitoring station over this time were generally in the range 1.5 to 8 m/s with the highest wind speeds (>8 m/s) occurring from south-easterly and north-westerly directions. Winds of this speed occur during 3.5 % of the observed hours during the years while calm winds (<0.5 m/s) occur during 3.7 % of hours on average across the years between 2018 and 2022. Meteorological data from 2020 was selected as representative for use in the AQIA.

The community of concern considered in this HHRA is the suburb of Kingswood (as outer suburb of Tamworth). This suburb includes residential properties, along with workplaces. Based on data from the 2021 Census, the suburb of Kingswood has a population of 1,142 people, with a median age of 45 years (slightly higher than the Greater Sydney median age of 37 years but like the median age of 43 years for the Rest of NSW).

Table 3.1 provides a summary of health data from the 2021 Census⁶, for Kingswood and the Tamworth LGA as well as Greater Sydney and the Rest of NSW. This table focuses on respiratory health.

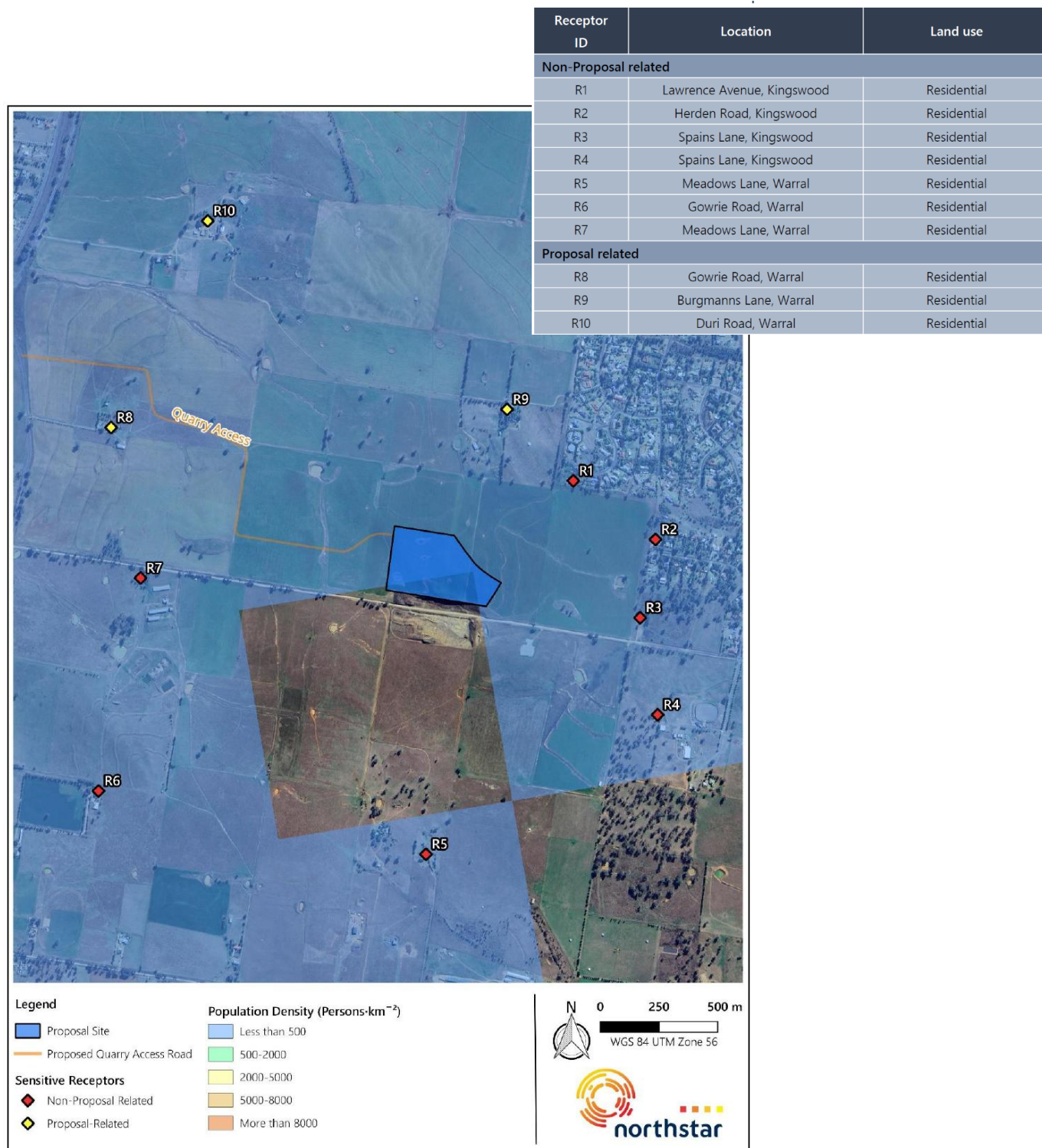
Table 3.1: Summary of 2021 census data – respiratory health

People with	Kingswood	Tamworth	NSW
Asthma	9.8%	11.2%	7.8%
Heart disease	4.6%	4.8%	3.9%
Lung condition (including COPD)	1.4%	2.3%	1.7%
Other long-term health condition	7.1%	8.2%	7.8%

⁶ <https://www.abs.gov.au/census/find-census-data/search-by-area>

3.4.2 Nearby sensitive receptors

Residential and rural dwellings are located adjacent to the project. Several discrete sensitive receptors are identified in the AQIA, as shown on **Figure 3.4**.



Source: Northstar

Figure 3.4: Nearby sensitive receptors (Northstar 2024)

3.5 Review of AQIA

The focus of this HHRA is the potential for quarrying activities at the project to generate dust, specifically PM_{2.5} that may contain RCS, and for this RCS to be present in the air within the local community.

Northstar (2024) outlines air dispersion modelling that was completed to estimate concentrations of PM_{2.5} in air at the local community during project construction and operations. This modelling was completed using the NSW EPA approved CALPUFF atmospheric dispersion model in 2-D mode (due to the uncomplicated topography). The modelling considered average and peak project activities, adopting emission factors for earthworks, materials handling processes, movement of trucks on unpaved roads, crushing and screening and wind erosion. The estimation of annual emissions assumed operations were performed at a steady rate across the year. The estimation of maximum 24-hour impacts assumed that the day of maximum activity occurs on every day of the year. This assumes the worst-case meteorological condition occurs at the same time as worst-case emissions, which was considered conservative. Emissions controls proposed for the project were also considered, including:

- minimising drop heights when unloading material
- water sprays on excavation area, transfer points and product stockpiles
- controlled crushing operations through mobile plant
- controlled screening operations through mobile plant
- low silt aggregate (i.e. gravel) on unpaved roads (site access)
- reduction in vehicle speeds to 20 km/hr on unpaved roads
- haul route watering (excluding site access)
- primary rehabilitation of bund area.

The result of the air dispersion modelling is an incremental impact from the project – this is the concentrations predicted as a result of the operation of the project in isolation, and a cumulative impact – this is the incremental concentrations predicted from the operation of the project as well as the background air quality concentrations adopted in the AQIA. The results for the incremental impact have been considered further in this HHRA i.e. the concentrations of PM_{2.5} predicted to be sourced from the project which may contain RCS.

The AQIA predicted the following incremental PM_{2.5} concentrations at sensitive receptors R1 to R10:

- annual average concentration of <0.1 µg/m³
- maximum 24-hour average concentrations in the range 0.5 to 2.4 µg/m³.

The modelling indicated that the higher incremental PM concentrations are primarily due to the use of the site access road. Watering of the road is recommended in the AQIA, where visible dust is observed. This will reduce predicted PM_{2.5} concentrations.

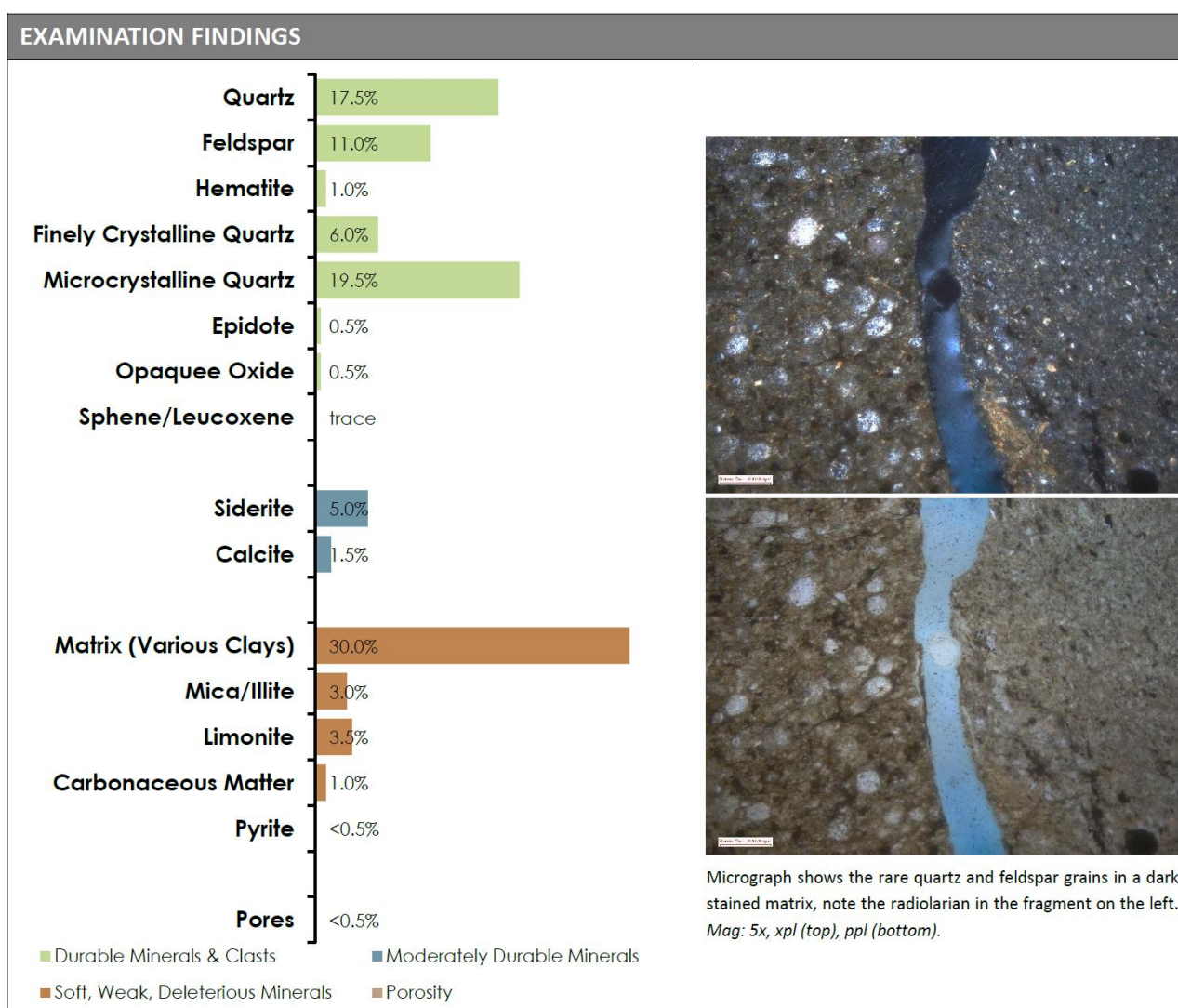
3.6 Quartz concentration in mudstone

The February 2026 Scope Geo Petrographic Report indicates that a sample (T4312A) was submitted for microscopic analysis in January 2026. The sample comprised fine crushed rock comprising moderately weathered grey, reddish grey and pale grey, very fine-grained sedimentary

rock (mudstone) with carbonaceous wisps. The sample was moderately durable in condition and potentially adequate for use as a construction material.

The free silica content was reported to be 43%, present as sand sized grains (17.5%), locked within various lithic clasts of finely crystallized quartz (6.0%) and microcrystalline quartz locked within the matrix intermingled with clays (19.5%). It is noted that this is the free silica content as quartz in the mudstone, not the RCS concentration in fine particles such as PM_{2.5}. However, the free silica content in the mudstone provides an indication of the RCS concentration in fine particles such as PM_{2.5}.

The findings of the Scope Geo Petrographic Report are shown below, and a copy of the report is provided in **Appendix B**.



Section 4. Assessment of health risks

4.1 General

This section presents a screening level assessment of potential health risks relevant to the Kingswood community, in relation to exposures to RCS that may be sourced from the Project.

4.2 Assessment of community exposure and health risks

The assessment of potential risks in the community has been undertaken via a screening level assessment. This has involved comparison of the predicted level of RCS in the air within the community with the health-based guideline identified in **Section 2.3**.

The health based guideline for RCS adopted for this assessment is $3 \mu\text{g}/\text{m}^3$ (OEHHA 2005) (EPA Victoria 2007). This guideline relates to an annual average concentration of RCS as $\text{PM}_{2.5}$ in air, where the community may be exposed. This guideline relates to total exposures to RCS (background exposures plus any incremental impact from the project).

In relation to exposures that may occur within the community, the following has been considered:

- existing or background exposures to RCS – no data is available for the area near the project, hence expected background level of RCS in air as discussed in **Section 2.3.1** (and **Appendix A**), of $1.9 \mu\text{g}/\text{m}^3$ has been adopted in this assessment. It is assumed that this background relates to RCS as $\text{PM}_{2.5}$
- potential impacts from the project – this has been modelled for the project (Northstar 2024), with the incremental increase in annual average $\text{PM}_{2.5}$ predicted to be $<0.1 \mu\text{g}/\text{m}^3$
- total maximum annual average RCS exposures as $\text{PM}_{2.5}$ are therefore $1.9 \mu\text{g}/\text{m}^3$, noting that the project does not contribute RCS above background levels
- this is less than the adopted guideline of $3 \mu\text{g}/\text{m}^3$.

On this basis, there are no health risk issues of concern in relation to community exposures to RCS in dust that may be sourced from the project.

The conclusion presented above assumes that 100% of the $\text{PM}_{2.5}$ is RCS, whereas the laboratory analysis of 1 sample of mudstone has indicated that the free silica content in the material is 43%. This does not change the outcome of the assessment as RCS potentially sourced from the project does not increase background concentrations of RCS in the environment. It does however add an additional margin of safety (conservatism) to the assessment.

In conclusion, RCS exposures in the community are low and there are no health risk issues of concern.

4.3 Uncertainties

4.3.1 General

The predicted $PM_{2.5}$ concentrations have been sourced from the AQIA (Northstar 2024) which has been undertaken in accordance with National and State requirements. The predicted $PM_{2.5}$ concentrations are based on a modelling exercise, where there is some uncertainty. However the incremental annual average $PM_{2.5}$ concentrations are not detected at a level 30 times below the adopted screening level guideline.

The adopted screening level guideline has been derived using a conservative process and is protective of all members of the community including sensitive individuals and children. The adopted screening level guideline is also supported by other international reviews.

However, as there are uncertainties throughout all stages of any risk assessment, it is important to consider how these uncertainties impact on the assessment presented. This uncertainty analysis has considered:

- the slightly lower screening guideline derived by TCEQ (2009) for the protection of silicosis
- the TCEQ (2009) screening level guideline for the protection of lung cancer
- the predicted maximum 24-hour average $PM_{2.5}$ concentrations
- the predicted PM_{10} concentrations.

Further discussion is provided below.

4.3.2 TCEQ (2009) TRVs

TCEQ (2009) has derived a slightly lower screening level guideline of $2 \mu g/m^3$ (versus the $3 \mu g/m^3$ adopted in the HHRA). This guideline is based on the same key toxicity studies but a different assumed silica content in dust that workers in the original study (e.g. the South African gold miners) were exposed to. From the differing views of the international organisations, it appears that the silica content that these workers were exposed to was not well documented/explained. Hence the assumptions adopted by TCEQ (2009) were more conservative. This guideline also relates to a threshold assessment of total exposure to RCS.

The maximum predicted concentrations of RCS in the community (which are consistent with background) are just less than or may be equal to this guideline. Where only the impact from the project is considered, total exposure is modelled to be 20 times below this guideline.

For the assessment of lung cancer effects, TCEQ (2009) adopted a non-threshold approach (which is different from other health agencies). This calculation relates to an incremental lifetime cancer risk and can only be compared with the incremental change in RCS predicted because of the project. The maximum increased in RCS predicted in the community from the project is $<0.1 \mu g/m^3$, which is below the incremental guideline of $0.29 \mu g/m^3$ established by TCEQ.

In addition, the following can also be noted:

- as discussed in **Appendix A4**, TCEQ (2009) indicates that the determination that RCS is carcinogenic relates only to occupational exposures. Hence, the comparison of $PM_{2.5}$

concentrations with the screening level guideline derived by TCEQ (2009) for protection against cancer is expected to overestimate these risks in the community

- the AQIA indicates that the assessment undertaken is designed to be protective of worst-case activities for the project.

This means that consideration of the TRVs established by TCEQ (2009) does not change the outcome of the assessment presented in this report – that there are no risk issues of concern in relation to community exposure to RCS derived from the project.

4.3.3 Maximum 24-hour average PM_{2.5} concentrations

The AQIA also predicts maximum incremental 24-hour average PM_{2.5} concentrations in the range 0.5 to 2.4 µg/m³ at sensitive receptors (R1 to R10).

The screening level guideline adopted in the HHRA is for chronic (long-term) exposures, not for short-term peaks such as a 24-hour average. In addition, the daily peaks in the concentrations are all considered in the calculation of an annual average concentration. Hence, it is not appropriate to compare the chronic screening level guideline adopted in the HHRA with the maximum 24-hour average concentration.

TCEQ (2009) derived a screening level guideline for acute exposures (a ReV) of 47 µg/m³. Maximum incremental 24-hour average PM_{2.5} concentrations (assuming RCS is 100% PM_{2.5}) are 20 times below this acute guideline.

This confirms that RCS exposures in the community are low and there are no health risk issues of concern.

4.3.4 PM₁₀ concentrations

In this uncertainty analysis, PM₁₀ concentrations have also been reviewed against the adopted screening level guideline given the recommendations of OEHHA (2005) which indicates that where PM_{2.5} < 3 µg/m³ but PM₁₀ > 3 µg/m³ concentrations may require further investigation, including a more precise determination of the respirable fraction (including the silica concentration in this fraction). As noted above, Victoria (and subsequently other states including NSW and Queensland) has adopted the OEHHA (2005) guideline for RCS as PM_{2.5}, and do not compare PM₁₀ concentrations to the guideline. Hence, the approach adopted is conservative. There is no information on background levels of RCS as PM₁₀, hence it is not possible to consider total exposures.

Northstar (2024) predicted that the annual average PM₁₀ concentrations that could be sourced from the Project and reach nearby sensitive receptors (R1 to R10) were in the range <0.1 to 0.5 µg/m³. These PM₁₀ concentrations remain below the adopted health-based guideline. Where the indicative RCS content of the analysed mudstone sample (43% free silica) is considered, the relevant concentration is a maximum of 0.22 µg/m³ which is 14 times below the adopted guideline (3 µg/m³).

This also assumes that all the PM₁₀ can be inhaled and would penetrate deep into the lungs, which is conservative, as only particles smaller than PM₅ are sufficiently small to penetrate deep enough into the lungs to be of concern. PM_{2.5} comprises a proportion of PM₁₀.



This confirms that RCS exposures in the community as a result of the proposed project are low and there are no health risk issues of concern.

Section 5. Summary and conclusions

Environmental Risk Sciences Pty Ltd (enRiskS) has been engaged by Quarry Plan NSW, on behalf of Oats Block Pty Ltd, to undertake a human health risk assessment (HHRA) in relation to potential exposures to respirable crystalline silica (RCS) from the proposed Strathmore Quarry (the “project”).

The focus of this HHRA is the potential for quarrying activities at the project to generate dust, specifically PM_{2.5} that may contain RCS, and for this RCS to be present in the air within the local community. The residential area of Kingswood is located approximately 550 m to the north-east of the project.

Exposures that are of most concern in relation to silica, relate to the inhalation of RCS. RCS refers to the presence of silica in fine dust particles that are small enough to be inhaled and penetrate deep into the lungs – i.e. PM_{2.5}. The crystalline shape of these fine particles has the potential to result in inflammation and the development of disease (including silicosis and lung cancer) where exposure occurs over a long period of time.

There are significant health effects that have been identified in relation to occupational exposures to RCS. The available data is limited in relation to supporting that these health effects may occur within the community, where exposures are significantly lower than within occupational environments. Regardless, guidelines are available in relation to the assessment of community exposure to RCS. These guidelines relate to long-term exposures to RCS in air as PM_{2.5}. The guideline adopted in this HHRA is 3 µg/m³. The guideline is for exposures by the community from all sources, including background concentrations of RCS in the environment.

Northstar (2024) outlines air dispersion modelling that was completed to estimate concentrations of PM_{2.5} in air at the local community (sensitive receptors R1 to R10) during project construction and operations. The modelled annual average incremental impact from the project (the annual average concentrations of PM_{2.5} predicted to be sourced from the project) have been considered in this HHRA. This HHRA has assumed that these concentrations are 100% RCS, as well as 43% RCS, the latter being the reported free silica content in 1 sample of mudstone from the project area.

The AQIA indicates that the predicted annual average incremental PM_{2.5} concentration at sensitive receptors R1 to R10 is <0.1 µg/m³. Hence, the project is not predicted to increase RCS as PM_{2.5} above the background level (1.9 µg/m³). Total predicted exposures to RCS remain below the adopted screening level guideline of 3 µg/m³.

The AQIA indicates that the higher incremental PM concentrations are primarily due to the use of the site access road. Watering of the road is recommended in the AQIA, where visible dust is observed. This will reduce predicted PM_{2.5} concentrations, further increasing the margin of safety in the HHRA.

Consideration of uncertainties present in the HHRA does not change HHRA outcomes.

On this basis, there are no health risk issues of concern in relation to long-term exposures to RCS in air within the community surrounding the project.

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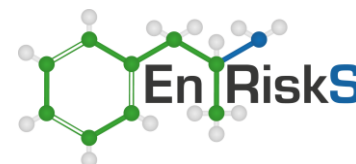
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Appendix A Toxicity of respirable crystalline silica

A1 Approach

The quantitative assessment of potential risks to human health for any chemical requires the consideration of the health end-points and where carcinogenicity is identified; the mechanism of action needs to be understood.

For chemicals that are not carcinogenic, a threshold exists below which there are no adverse effects (for all relevant end-points). The threshold typically adopted in risk calculations (a tolerable daily intake [TDI] or tolerable concentration [TC]) is based on the lowest no observed adverse effect level (NOAEL), typically from animal or human (e.g. occupational) studies, and the application of a number of safety or uncertainty factors. Intakes/exposures lower than the TDI / TC is considered safe, or not associated with an adverse health risk (NHMRC 1999).

Where the chemical has the potential for carcinogenic effects the mechanism of action needs to be understood as this defines the way that the dose-response is assessed. Carcinogenic effects are associated with multi-step and multi-mechanism processes that may include genetic damage, altering gene expression and stimulating proliferation of transformed cells. Some carcinogens have the potential to result in genetic (DNA) damage (gene mutation, gene amplification, chromosomal rearrangement) and are termed genotoxic carcinogens. For these carcinogens it is assumed that any exposure may result in one mutation or one DNA damage event that is considered sufficient to initiate the process for the development of cancer sometime during a lifetime (NHMRC 1999). Hence no safe-dose or threshold is assumed, and assessment of exposure is based on a linear non-threshold approach using slope factors or unit risk values.

For other (non-genotoxic) carcinogens, while some form of genetic damage (or altered cell growth) is still necessary for cancer to develop, it is not the primary mode of action for these chemicals. For these chemicals, carcinogenic effects are associated with indirect mechanisms (that do not directly interact with genetic material) where a threshold is believed to exist.

Dose-response values (threshold or non-threshold) that are considered relevant to the characterisation of potential health effects associated with exposure to the CoPCs identified have been selected from credible peer-reviewed sources as outlined in enHealth (enHealth 2012a) and NEPM (NEPC 1999 amended 2013b).

A2 General

The US Agency for Toxic Substances and Disease Registry (ATSDR) released an updated Toxicological Profile for Silica in September 2019 (ATSDR 2019). This toxicity profile is based on the information presented in the ATSDR document, with support from other references where indicated.

Silica in the form of quartz is one of the most commonly occurring minerals on the Earth's surface, with over 95% of the earth's crust made of minerals containing silica. There are 2 forms of silica – crystalline silica and amorphous silica. Amorphous silica lacks a crystalline structure. Two common forms of crystalline silica are quartz and cristobalite.

Silica from quartz is an odourless, white, black, purple or green solid and is generally considered to be insoluble in water and unreactive in the environment. RCS in dust is also considered stable.

Amorphous silica is more soluble than crystalline silica, hence, the primary source of dissolve silica in water is amorphous silica. Any silica that does not dissolve settles as sediment.

Silica is naturally released into the environment through the weathering of rocks, volcanic activity and biogenic sources. Hence, background exposures may occur through air, indoor dust, food, water, soil and various consumer products. Crystalline silica has a wide variety of commercial and industrial uses including:

- to produce high-temperature or refractory silica brick, foundry moulds and cores for metal casings
- to manufacture glass and pure silicon for computer chips
- as a filler in asphalt, plastics, rubber and paint
- as an abrasive (e.g. for blasting)
- in sand and gravel used for building roads and in concrete
- in the water-sand mix used by the oil and gas industry to fracture rock
- in bricks, mortar, plaster, calk, roofing granules and stone building materials (including benchtops)
- in art clay, glazes and gemstones in jewellery
- in personal care products such as cleansers and talcum powder and cosmetics
- in pet litter and furniture foam.

A3 Exposure, absorption and health effects

The exposure route of concern for RCS is inhalation. Exposure to RCS is known to occur in industrial and occupational settings, with RCS recognised as an important occupational inhalation hazard.

The mechanisms that contribute to the absorption of inhaled particles are the physical transformation of particles deposited in the lung (including any surface modification or fragmentation), the dissolution of particles and interactions of particles with macrophages. Macrophages are cells in the immune system that recognise, eat and destroy target cells. The activity of macrophages is the dominant mechanism by which RCS is absorbed from the pulmonary region (referred to as “the lungs” in this review).

After being inhaled, RCS is cleared from the lungs via lymph drainage, macrophage phagocytosis and migration, and upward mucociliary flow. However, the presence of RCS in the pulmonary region also triggers cytotoxicity (toxicity to cells in the lungs) and apoptosis (cell death) leading to impaired clearance of the inhaled RCS. Dissolution does not play a strong role in RCS clearance due to the low solubility of silica. Absorbed RCS is not metabolised but may be transported to the lymph nodes following inhalation and may be excreted in the urine. Hence, inhaled RCS is not easily removed from the lungs.

Health effects associated with inhaled RCS reported in the scientific literature are strictly associated with occupational exposures to particles that are of respirable size (i.e. $<10\text{ }\mu\text{m}$) in silica industries. These effects include acute as well as chronic health effects.

Acute silica exposure causes respiratory tract inflammation. It also stimulates a significant increase in alveolar macrophages, leading to elevated levels of reactive oxygen species (ROS), which plays an important part in inflammation and the production of antioxidant compounds.

When poorly soluble particles, such as RCS, are inhaled they are deposited in the lungs, where long term inflammation results in disease such as silicosis and fibrosis. The prolonged inflammation results in the formation of fibrotic scar tissue and degradation of the muco-ciliary escalator (lung clearance mechanism). The improper repair of damaged lung tissue is essential for the development of chronic disease.

Health effects associated with occupational exposures include silicosis, lung cancer, renal toxicity and autoimmune diseases. The health effects that are generally of greatest concern to humans are silicosis and lung cancer

Silicosis is a progressive and irreversible fibrotic lung disease that has been recognised since Roman and Greek times and is not caused by any substance other than RCS (including amorphous silica). A fibrotic lung disease is a disease where excess fibrous connective tissue is formed in an organ. This type of effect is also referred to as scarring when in response to an injury. Silicosis is caused by inhaling RCS, where the RCS is then deposited on the lungs. There is no known cure for silicosis. There are several types of silicosis:

- **Acute silicosis** is caused by intense exposure to fine RCS dust, such as those generated during blasting or tunnelling. With this disease, the alveolar (the tiny air sacks in the lungs which absorb oxygen) fill with a protein rich fluid containing damaged cells. Inflammation of the lung also occurs. Symptoms include laboured breathing, dry cough, decreased pulmonary function, fever and fatigue followed by cyanosis and respiratory failure.
- **Simple silicosis** is the most common type of silicosis and results from long periods (10 to >20 years) of continuous exposures to relatively low levels of RCS dust. Primary function and general health is typically not compromised in the early stages, however, intensity of cough and mucous discharge increases as the disease progresses. Decreases in lung function are often observed (including non-reversible air flow obstruction).
- **Progressive massive fibrosis (PMF)** is a progression of simple silicosis where nodular lung lesions (injuries) grow and come together to form masses of connective tissue that ultimately destroys the lung structures including the blood vessels. This leads to restricted lung volume and poor gas exchange.
- **Accelerated silicosis** is a progressive form of simple silicosis that develops 5 to 10 years after exposure and is typically associated with moderate exposures (as opposed to simple silicosis which is associated with lower level exposures). Symptoms are similar to those of simple silicosis.

Decreased lung function can also be observed in the absence of silicosis and may be caused by exposures to RCS. This is known as chronic obstructive pulmonary disease (COPD). COPD is characterised by limitation in airflow caused by chronic bronchitis, emphysema, asthma or peripheral airways disease (ATSDR 2019; NIOSH 2002). Cigarette smoking is the main cause of COPD however occupational exposures to dust and community air pollution can also contribute and there are limited studies that link RCS and COPD. No studies have investigated a potential link between RCS and asthma and RCS is not known to cause asthma occupationally.

The most important factor for the development of silicosis is cumulative exposure to RCS. Time from first exposure to onset of symptoms can vary from a few weeks (for acute silicosis) to 20 years or more (for simple silicosis). Disease severity may also slowly increase following cessation of exposure, where RCS is retained in the lungs.

Several studies have looked at whether exposure to RCS causes lung cancer and compared to other occupational lung carcinogens, the reported association is low. However, an increased risk to lung cancer in RCS workers has been reported, with risks dependant on cumulative (successive and ongoing) exposures over times. The available evidence indicates that RCS is genotoxic with the ability to cause mutagenicity and DNA damage.

The major biological processes thought to cause silicosis and lung cancer are shown in **Figure A1**, and there appears to be some evidence that silicosis is more prevalent in situations where the silica inhaled is freshly fractured (where the silica particles may generate free radicals).

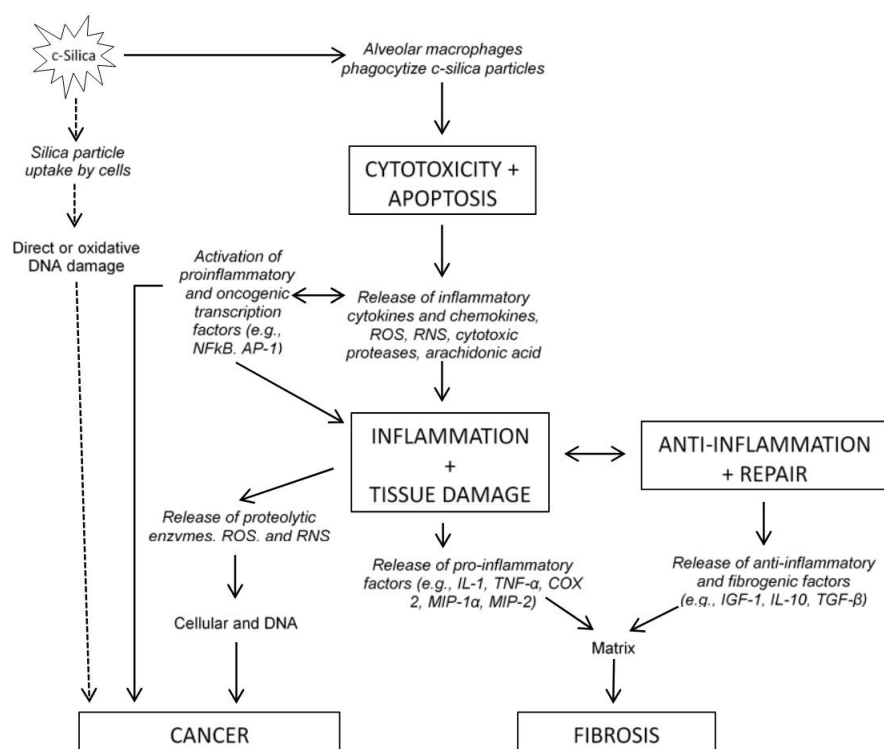


Figure A1: Biological pathways for the formation of silicosis and lung cancer (ATSDR 2019)

Exposure to RCS can also cause adverse renal and autoimmune outcomes. However, these effects are not as well studied as silicosis and lung cancer and associations are not evident in all studies. It is considered that renal toxicity occurs at higher exposure levels than silicosis.

Data on health effects following oral exposures to RCS is also limited. However, the available studies do not identify adverse effects in animals following exposures via this route (no data is available for humans). Similarly, adverse effects in humans and animals are expected following dermal exposures.

No information is available in relation to the susceptibility of children to RCS as silicosis is generally considered to be an occupational disease that typically appears after prolonged exposures. The same adverse effects would be expected to appear in children where exposures were similar to adult workers. Individuals with underlying lung and health conditions such as asthma and emphysema may be more susceptible to adverse respiratory effects from inhaled RCS. The risk of silicosis in workers who smoke cigarettes is also higher than in workers who do not smoke.

The presence of silica in the urine indicates that exposure has occurred. However, the presence of silica in the urine does not provide any specific information in relation to exposure levels and/or the potential for adverse health effects.

A4 Classification

Inhaled crystalline silica dust in the form of quartz or cristobalite, is classified as Group 1 (carcinogenic to humans) by the International Agency for Research on Cancer (IARC) (IARC 2012).

The IARC classification is based on data from human workers in 5 main industrial settings comprising ceramics, diatomaceous earth facilities, ore mining, quarries, and sand and gravel operations. Of these settings, the data from diatomaceous earth facilities, quarries, and sand and gravel facilities was concluded to be least likely to be confounded (i.e. influenced by factors other than the presence of RCS). Most studies from these 3 industries reported associations between RCS exposure and lung cancer risk. Cancers other than lung cancer have not been as thoroughly researched. RCS has been demonstrated to be a lung carcinogen in experimental rats but not in mice and hamsters. It is noted that rats are generally considered more likely to get lung tumours than mice and hamsters. The mechanism for carcinogenicity is likely to be inflammation. As noted above, RCS is thought to be genotoxic.

TCEQ (2009) notes that the carcinogenic potential of silica is controversial with statistically significant associations observed in some studies but not other studies. This may be due to the specific type of crystalline silica inhaled or on other external factors that affect biological activity and distribution (for example quartz is known to be variable where toxicity may be dependant on the surface characteristics and age of the particles, as well as other factors including confounding). There is epidemiological evidence that the risk of developing lung cancer is higher in workers with silicosis than those without silicosis, however it is not known if silicosis is necessary for the development of lung cancer.

TCEQ (2009) also emphasises that the identification of RCS as carcinogenic relates only to occupational exposures. This is because no epidemiological studies were available to IARC on environmental exposures at the time of the assessment.

The classification of RCS as an occupational carcinogen is supported by ACGIH (2010) which indicates that the consensus among US and international agencies is that there is a positive association between silica exposures and lung cancer. Most agencies consider that silica does not directly act to initiate cancer, however, do agree that workers that have pulmonary fibrosis (following exposure to silica) are at risk of developing lung cancer (but does not prove that the fibrosis leads directly to lung cancer). However, ACGIH considers that a reduction in worker exposures such that risks from silicosis are eliminated will likely protect against the formation of lung cancer.

Silica is not currently identified by USEPA or TCEQ (TCEQ 2009) as having a mutagenic mode of action and data is not adequate to determine the mechanisms or key steps that are critical for lung cancer development, and hence the potential for increased susceptibility in children due to early life exposure.

A5 Quantitative toxicity reference values

Toxicity reference values (TRVs) are quantitative values that are derived by key health authorities to be protective of the health effects that have been identified for a chemical. This involves an understanding of the different types of health effects that have been identified. It is often the case that different health effects occur at different levels of exposure. The detailed reviews that are undertaken by health authorities identify what the most sensitive health effect is and what would be the lowest, or most protective, quantitative value. This is the TRV, and it is established to be protective of all health effects.

For RCS, the information summarised above (and presented in the references noted) has been considered by several different health authorities. **Table A1** summarises the non-threshold and threshold chronic toxicity reference values (TRVs) that are available for RCS from Level 1 Australian and international sources. Two types of toxicity values are listed in this table:

- **Occupational air guidelines:** these guidelines are applicable to individuals who are exposed to chemicals in the workplace through use or handling, that does not present an unacceptable risk to worker health or cause undue discomfort. These guidelines relate exposures by healthy workers in the workplace, during work hours. The guidelines are higher than ambient or community air guidelines and may be at levels that are mildly irritating; and
- **Community air guidelines:** these guidelines represent the concentration of a chemical in air that, based on the current science, does not present an unacceptable risk to public or community health. These guidelines are based on a range of different studies conducted in animals and humans (from occupational studies or studies in large populations – epidemiological studies), with the application of an uncertainty factors to make sure that the guideline is relevant to the community who may have a range of sensitivities. The uncertainty factors may also take into account any limitations there are with the available studies.

The community air guidelines are the guidelines that are relevant for the assessment of potential health risks to residents that may be exposed to RCS in dust sourced from the Quarry. The occupational air guidelines have been provided for reference, as many of the health effects identified are of most significance for occupational exposures.

Table A1: Summary of relevant TRVs for RCS

Source	Value	Basis/Comments
Occupational Air Guidelines		
Australian		
Safe Work Australia ⁷ Work Safe Victoria ⁸ Safe Work NSW ⁹ AIOH ¹⁰	50 µg/m ³	Workplace exposure standard (WES) as a Time-weighted Average (TWA) for the respirable fraction of each of the following forms of airborne crystalline silica: Cristobalite, Tridymite, Tripoli, and Quartz. A TWA applies to an 8-hour workday during a 40-hour work week. In additional, exposures should be kept as low as is reasonably practicable to protect workers and others in the workplace. The TWA was revised down 100 µg/m³ in December 2019. The Draft document supporting the derivation of the revised TWA indicates that there is no clear no observable adverse effect concentration (NOAEC) in humans however concentrations below 25 µg/m³ are considered to be protective of the lungs by ACGIH and multiple data sources identify adverse effects in the lungs at 50 µg/m³ and lung cancer at 65 µg/m³. Concentrations of 20 µg/m³ are considered protective against both silicosis and lung cancer, with lung cancer considered a secondary effect to silicosis. However, implementation of a WES of 20 µg/m³ was not considered practicable. From 1 December 2026, the WES will transition to workplace exposure limits (WEL). The value of the standard remains the same (WEL = 50 µg/m³) and persons conducting a business or undertaking (PCBUs) must ensure that no person at the workplace is exposed to an airborne contaminant at a level above this limit. Work Safe Victoria and the Australian Institute of Occupational Hygienists Inc (AIOH) reference Safe Work Australia.
International		
WHO (WHO 2000)	None	No threshold or tolerable concentration identified. Recommends that occupational exposures to respirable quartz dust be reduced to the extent practicable.
NIOSH ¹¹ (NIOSH 2002)	50 µg/m ³	Recommended Exposure Limit (REL) for crystalline silica as respirable dust and a 10-hour workday during a 40-hour workweek. A no observable adverse effect level (NOAEL) was unable to be determined. The REL recognises that the sampling and analytical methods used to evaluate occupational exposures to RCS are not accurate enough to quantify exposures at concentrations below the REL. The REL is aimed at reducing the risk of developing silicosis, lung cancer and other adverse health effects. Substitution of less hazardous materials is also recommended where feasible.

⁷ <https://www.safeworkaustralia.gov.au/safety-topic/hazards/silica/whs-duties-silica/workplace-exposure-standard-respirable-crystalline-silica>

⁸ <https://www.worksafe.vic.gov.au/dust-containing-crystalline-silica-construction-work>

⁹ <https://www.safework.nsw.gov.au/hazards-a-z/hazardous-chemical/priority-chemicals/crystalline-silica/work-safely-with-crystalline-silica-and-engineered-stone>

¹⁰ https://issuu.com/thefilter/docs/what_do_i_need_to_know_about_air_monitoring?fr=xKAE9_zMzMw

¹¹ <https://www.cdc.gov/niosh/idlh/14808607.html>

Source	Value	Basis/Comments
		NIOSH defines the “respirable” fraction as “the portion of airborne crystalline silica that is capable of entering the gas-exchange regions of the lungs if inhaled; by convention, a particle-size-selective fraction of the total airborne dust; includes particles with aerodynamic diameters less than approximately 10 µm and has a 50% deposition efficiency for particles with an aerodynamic diameter of approximately 4 µm.” ¹²
Cal/OSHA ¹³	25 µg/m ³	Permissible Exposure Limit (PEL) enforced in workplaces under the jurisdiction of the California Division of Occupational Safety and Health. The PEL applies to the respirable fraction as defined by NIOSH. The PEL is the maximum permitted 8-hour time-weighted average (TWA) concentration of an airborne contaminant.
ACGIH (ACGIH 2010) ¹⁴	25 µg/m ³	Threshold Limit Value (TLV) for α-quartz and cristobalite and the protection against both silicosis and lung cancer. RCS classified as A2 – suspected human carcinogen. The TLV is based on the following: <u>α-quartz</u> Based on no change in longevity of lung function in workers exposed to 50 µg/m ³ , an increase in risk from silicosis in workers at 60 µg/m ³ , and an increase in risk from lung cancer in workers at 65 µg/m ³ . The TLV is based on the association of inflammation and fibrosis with lung cancer following silica exposures. The uncertainties associated with the epidemiological studies are noted and the industrial hygienist is advised to use every means available to keep exposures below the TLV. <u>Cristobalite</u> TVL for α-quartz recommended as the available human studies indicate a similar toxicity.
Community Air Guidelines		
Australian		
EPA Victoria (2007) ¹⁵	3 µg/m ³ (PM _{2.5} fraction)	Annual average assessment criteria for mining and extractive industries for RCS. This is the total concentration of background plus emissions arising from activities at a site. The assessment criteria are used to evaluate the impact of any residual emissions following appropriate controls. The REL from the California EPA Office for Environmental Health Hazard Assessment (OEHHA) has been adopted (refer below).
SA Government (2016) ¹⁶	0.36 µg/m ³ (PM _{2.5} fraction)	3-minute maximum ground level concentration as quartz or cristobalite from Schedule 2 of the Environment Protection (Air Quality) Policy 2016. No information available in relation to the derivation of the standard, hence, this standard has not been considered further. SA EPA (2022) (refer below) notes that the ground level concentration criteria listed under Schedule 2 of the Air EPP will be updated based on the outcome of the National Clean Air Agreement Work Plan 2021–23, using the most recent and applicable health-based science.

¹² <https://www.cdc.gov/niosh/docs/2002-129/pdfs/2002-129.pdf>

¹³ https://www.dir.ca.gov/title8/1532_3.html

¹⁴ <https://www.acgih.org/silica-crystalline-a-quartz-and-cristobalite/>

¹⁵ <https://www.epa.vic.gov.au/sites/default/files/epa/publications/1191.pdf>

¹⁶ [https://www.legislation.sa.gov.au/_/legislation/lz/c/pol/environment%20protection%20\(air%20quality\)%20policy%202016/2022.10.05/2016.-.un.pdf](https://www.legislation.sa.gov.au/_/legislation/lz/c/pol/environment%20protection%20(air%20quality)%20policy%202016/2022.10.05/2016.-.un.pdf)

Source	Value	Basis/Comments
SA EPA (2022) ¹⁷	3 µg/m ³ (PM ₁₀ fraction)	South Australia Interim criteria for respirable crystalline silica concentration in ambient air for mining and extractive industries. The selection of the PM ₁₀ size fraction is stated to be based on a precautionary approach, which will ensure communities are well protected from any adverse impact of RCS in ambient air. This interim policy position is in line with the modern assessment criteria used by the EPA Victoria and other jurisdictions in Australia and overseas. With respect to development and public protection exposure to RCS, the EPA will adopt the above approach pending the outcomes of the national review and any consequent updating of the Air EPP
International		
TCEQ (TCEQ 2009) ¹⁸	Non-cancer: = 2 µg/m ³ (PM ₄ fraction) Cancer: 0.27 µg/m ³ (PM ₄ fraction)	Effects Screening Levels (ESLs) for quartz, cristobalite, tripoli and tridymite. <u>Non-cancer effects:</u> Chronic Reference Value (ReV) based on epidemiological data from 2 studies. The key study involved South African gold miners (Hnizdo and Sluie-Cremer 1993; 2,235 individuals following 24 years exposure mainly to RCS as quartz). The supporting study involved Californian diatomaceous earth workers (Hughes et. al. 1998; 2,342 individuals exposed for at least 1 year to cristobalite). Bench-mark dose modelling was undertaken at the 1% response rate for both studies. The adopted point of departure was in the range 4 to 6 µg/m ³ . The adopted uncertainty factor (UF) was 3 to account for susceptibility in the general population (including children and the elderly). An UF of 3 was assessed to be adequate as a BMCL ₀₁ could be derived and the cohort examined was large and therefore assessed to cover sensitive sub-populations. However, the study only included male workers. The derived ReV was 2 µg/m ³ , based on the rounding of results from both studies. A chronic non-cancer ESL of 0.6 µg/m ³ was also derived based on a Hazard Quotient (HQ) of 0.3 (this is not relevant to Australia where the applicable HQ is 1). <u>Cancer:</u> Unit Risk (UR) of 3.6x10 ⁻⁵ (µg/m ³) ⁻¹ derived based on lung cancer mortality in silica-exposed workers (as pooled by Steenland etc. al. 2001; 65,980 workers from a range of industries) and RCS of ≤4 µm in diameter. The derived chronic ESL (cancer) was 0.00027 mg/m ³ at a target risk level of 1x10 ⁻⁵ .
Minnesota Department of Health (MDH 2013)	3 µg/m ³ (PM fraction not stated)	<u>Non-cancer effects:</u> Chronic Health Based Value (HBV) based on the same key epidemiological study evaluated by TCEQ (2009) (Hnizdo and Sluie-Cremer 1993), with a point of departure of 0.0098 mg/m ³ and an UF of 3. The main difference in the TCEQ and MDH assessments was the assumed %RCS in dust inhaled by the workers (30% by MDH versus 54% by TCEQ; a difference of around 2-fold). <u>Cancer:</u> No cancer HBV was calculated. MDH concluded that if exposure to silica is maintained at levels below the Chronic HBV the likelihood of increased risk of developing lung cancer is minimal.
California OEHHA (OEHHA 2005)	3 µg/m ³ (PM ₄ fraction)	<u>Non-cancer effects:</u>

¹⁷ https://www.epa.sa.gov.au/files/15448_rcs_interim_position.pdf

¹⁸ https://www.tceq.texas.gov/downloads/toxicology/dsd/final/silica_crystalline_forms.pdf

Source	Value	Basis/Comments
		Inhalation Reference Exposure Level (REL) based on the same key epidemiological study evaluated by TCEQ (2009) (Hnizdo and Sluie-Cremer 1993), with a point of departure of 9.8 µg/m ³ and an UF of 3. The assumed silica content in dust was 30%. Data from the Hughes et. al. (1998) study and 3 additional supporting studies (Chinese tin miners, Chen et. al., 2001; Dakota gold miners, Steenland and Brown 1995; South African gold miners, Churchyard et. al. 2004) was also considered. Derived RELs were in the range 3 to 6 µg/m ³ . The REL applies to the respirable fraction as defined occupationally by ACGIH (2004)/ISO (1995) which has a 50% cut-off point at the 4 µm particle aerodynamic diameter. <u>Cancer:</u> OEHHA notes that RELs are not derived based on cancer endpoints and there are no approved cancer potency factors for silica.
Vermont Agency of Natural Resources (2018) 19	0.12 µg/m ³ (PM fraction not stated)	Hazardous ambient air standard (annual average) for crystalline silica as listed in the 2022 Air Pollution Control Regulations. No information available in relation to the derivation of the air standard, hence, this standard has not been considered further.

¹⁹ https://dec.vermont.gov/sites/dec/files/aqc/laws-regs/documents/Vermont_Air_Pollution_Control_Regulations.pdf

As noted above, the community air guidelines presented in **Table A1** are the guidelines that are relevant for the assessment of potential health risks to off-site residents that may be exposed to RCS in dust sourced from the Quarry. The community air guidelines are lower than the occupational guidelines by around 10 to 30 times.

International community air guidelines for RCS are similar (2 to 3 $\mu\text{g}/\text{m}^3$) and are all based on protection against silicosis from data from occupational studies. The guideline of 3 $\mu\text{g}/\text{m}^3$ was first derived by OEHHHA (2005), was confirmed by the most recent review undertaken by MDH (2013) and adopted by EPA Victoria (2007). Hence, this guideline has been adopted in this HHRA. This means that exposures to RCS concentrations of less than 3 $\mu\text{g}/\text{m}^3$ are considered safe, or not associated with adverse health risks from RCS. A slightly lower guideline of 2 $\mu\text{g}/\text{m}^3$ has been derived by TCEQ (2009) but is noted to be based on the same key studies and is not significantly different to 3 $\mu\text{g}/\text{m}^3$.

The OEHHHA (2005) guideline specifically considered the protection of sensitive members of the population, especially children (as silica particles may penetrate further into the airways) and women (who may be more sensitive than men to the development of silicosis). For this reason, an UF of 3 (and not 1) was used for interspecies variation in the development of the air guideline, as the key studies primarily investigated effects in male workers. MDH (2013) notes that the derived guideline also considers general population exposures and is based on a benchmark concentration low_{01} (BMCL_{01} ; a value similar to a NOAEL) which is the 95% lower bound estimate of the concentration at which 1% of the population will develop silicosis.

Except for TCEQ (2009), national and international guidelines for cancer effects have not been derived, as silicosis was determined to be the most sensitive effect. i.e. cancer was deemed unlikely to occur at concentrations of RCS below the guideline for silicosis. The rationale for the inclusion of the cancer guideline by TCEQ (2009) appears to be based on the TCEQ policy position in relation to the lack of a clearly identified mode of action for silica toxicity, including the potential uncertainties in the epidemiology studies. In their response to comments on the Draft document outlining the derivation of the guidelines, TCEQ indicate that:²⁰

- *“There is not a consensus among the scientific community on whether the carcinogenic mode of action for silica is non-linear or linear or whether silicosis is necessary for the development of lung cancer”.*

The opinion of TCEQ (2009) is not supported by the more recent MDH (2013) review who indicate the following:

- *Silica has been classified as a known human carcinogen...because of an observed increase in lung cancers in occupationally exposed workers. There is, however, a large body of evidence that indicates that lung cancer attributed to silica occurs only after repeated insult leads to silicosis. While some controversy remains, MDH has determined that if exposure to silica is maintained at levels below those that result in silicosis the likelihood of increased*

²⁰ https://www.tceq.texas.gov/assets/public/implementation/tox/dsd/final/october09/comments/responses_silica.pdf

risk of developing lung cancer is minimal. MDH will continue to monitor this issue and reconsider this decision as new information becomes available.

In the absence of a definitive mode of action, TCEQ guidance indicates that where chronic adverse effects are determined to be associated with a linear dose-response relationship in the low-dose region, which is typically for chronic exposures to carcinogens, a cancer evaluation should be undertaken. This determination is based on data or science policy default assumptions (TCEQ 2006).

Irrespective of the above, IARC is clear that the determination that RCS is carcinogenic relates only to occupational exposures. For this reason, the TCEQ (2009) cancer guideline has not been adopted in this HHRA.

In relation to the OEHHA (2005) community air guideline (REL), the background document notes that there is an absence of comprehensive data on the ability of different particle sizes to induce silicosis, hence, it is not possible to adjust the guideline for different size particle distributions (e.g. as might be measured at a particular site). Further, while silicosis is generally assumed to be induced by the fraction that reaches the alveoli (with the majority of particles around 4 µm), there is no data to confirm a lack of adverse effects for coarser particles of 4 to 10 µm. Hence OEHHA indicates that the guideline applies to particles that are defined as “occupationally respirable”. Given this:

- silica as PM_{2.5} and PM₁₀ concentrations ≤3 µg/m³ would not be expected to be associated with adverse health effects
- silica as PM₁₀ concentrations >3 µg/m³ require further investigation and/or risk management, and
- silica as PM_{2.5} >3 µg/m³ < PM₁₀ concentrations may require further investigation, including a more precise determination of the respirable fraction.

Victoria (EPA Victoria 2007) has adopted the OEHHA (2005) guideline for RCS as PM_{2.5}. This guidance is adopted in the *Protocol for Environmental Management: Mining and Extractive Industries, State Environment Protection Policy (Air Quality Management)* (in a PEM that was part of the previous legislative instrument for air quality in Victoria).

South Australia has adopted the OEHHA (2005) guideline for RCS as PM₁₀, noting that this is a precautionary approach. South Australia also notes that *“This level is an especially cautious estimate as it is based on the size of the dust particles in the air, specifically all particles smaller than 10 micrometres in diameter, but RCS particles of most concern are those respirable particles that are smaller than four micrometres in diameter. This means that the criterion probably assumes a higher level of exposure than what actually occurs from the most concerning size fraction and is more protective.”*²¹ The guidance from South Australia is marked “Interim”.

²¹ <https://www.sahealth.sa.gov.au/wps/wcm/connect/ed49a8ef-30df-40f5-abc9-58d8e791fad7/300625+-+Respirable+Crystalline+Silicosis+Exposure+in+Non-workplace+Settings.pdf?MOD=AJPERES&CACHEID=ROOTWORKSPACE-ed49a8ef-30df-40f5-abc9-58d8e791fad7-pv3it9a>

It is noted that the definition of “occupationally respirable” (which are generally particulates with 50% cut-point at 4 μm aerodynamic diameter, noting that some studies use variations around 4 to 5 μm) is different to environmental definition of respirable as PM_{10} . Much of the data used to determine the guidelines provided by OEHHA (and other guidelines) are based on occupational measurements of respirable silica. Hence application of the OEHHA values for PM_{10} is complex and has uncertainties. TCEQ (TCEQ 2009) considered the particle size measured in the key studies that inform the chronic guidelines and determined that the guidelines apply to respirable crystalline silica $\leq 4 \mu\text{m}$ in diameter.

A6 Environmental silicosis

As noted above, RCS is recognised as an important occupational inhalation hazard. However, information in relation to the potential for silicosis in the general population is less available.

ATSDR (2019) indicates that the primary route of exposure to RCS in the non-occupational population is through to be via the inhalation of RCS during the use of commercial products containing quartz. People who live near quarries, sand or gravel operations or hydraulic fracturing operations may be exposed to RCS in dust. However, to date adverse health effects associated with inhaled RCS have been strictly associated with occupational exposures to particles that are of respirable size (i.e. $<10 \mu\text{m}$). Adverse effects of RCS have not been reported for incidental exposure to low levels of RCS in the environment (e.g. in beach sand) or from exposures that exceed the respirable size fraction.

A USEPA report into ambient levels of RCS indicates that environmental silicosis is not a well-defined term (USEPA 1996). Although some studies have reported silicosis in the absence of occupational exposures, most studies reporting pulmonary ailments following ambient dust exposures are from underdeveloped arid regions of the world, and in general, the studies lack control patients and/or specific silica dust exposure measurements. These studies often do not clearly differentiate between occupational and environmental exposures. OEHHA (2005) confirms that several international studies have reported environmental silicosis, which is where the silicosis occurs in the absence of an industry usually associated with the disease. However, in the instances reviewed, the exposures were high and therefore considered to be the same as occupational exposures, or to express this another way, higher than exposures by most of the population.

The main example provided by OEHHA (2005) (and by other reviews in the scientific literature) is the instances of pneumoconiosis in Ladakh, India. Pneumoconiosis is a group of diseases of the lung caused by the inhalation of dust, which include silicosis. The Ladakh area is high in the western Himalayas where there are no mines or industries. In around 450 randomly selected inhabitants across three villages (Saboo, Shey and Chushot), the prevalence of pneumoconiosis was 2.0% (3/150) in Saboo, 20.1% (31/149) in Shey and 45.3% (68/150) in Chushot. The prevalence of pneumoconiosis was observed to correspond with the severity of dust storms and the presence or absence of chimneys in kitchens. Without chimneys (Chushot), dust concentrations in kitchens averaged $7,500 \mu\text{g}/\text{m}^3$ during cooking periods. The free silica content of the dust storms was 60-70%. The authors suggested that the pneumoconiosis was due to exposure to free silica from dust storms and to soot from cooking with domestic fuels (with effects potentially affected by the interaction of silica and soot). Similar findings have been reported following studies with Bedouin

women who undertake work including spinning wool, cooking and cleaning tents, in individuals involved in occupations with high exposures to silica dust such as farmers or woodworkers (USEPA 1996) and in other Himalayan villages that are exposed to frequent dust storms (Bhagia 2012). These situations could also be considered equivalent to exposures adjacent to industries in developing countries such as India and South Africa (refer to **Table A1**) where monitoring and/or risk mitigation measures are not routinely implemented.

There is evidence of silicosis among domesticated grazing animals (horses, camels and water buffalo). This indicates the potential for environmental silicosis however the specific relevance of these findings to humans is not clear. It is also noted that the utilised diagnostic techniques (e.g. chest X-rays) may have overlooked low levels of environmental silicosis in the general population, particularly in dusty/arid regions (USEPA 1996).

As noted above, some key limitations of the studies in the scientific literature relating to environmental silicosis is data on concentrations for RCS in air that the study population was exposed to, as well as the presence of confounding exposures (in particular particles from cooking and heating with no controls). However, data is available from 2 air monitoring studies undertaken in the USA and UK where RCS concentrations were reported. This data is summarised below.

Air monitoring for RCS was undertaken in Wisconsin USA between 2012 to 2014 in response to community concern in relation to ambient RCS concentrations adjacent to frac sand production facilities (Richards & Brozell 2015). Multi-year sampling programs were undertaken adjacent to 4 facilities, of which 3 were frac sand mines and 1 was a frac sand processing plant. Sampling locations were around 600 to 1,300 m from the facilities and considered the prevailing wind direction/s. A total of 2,128 24-hour average sample values were available, across the 8 sampling locations at the 4 facilities.

The RCS concentration in the PM₄ fraction was measured, with 88% of samples reporting RCS below the limit of reporting of 0.31 µg/m³. Geometric means of 0.22 to 0.41 µg/m³ were reported for the analysed yearly datasets, depending on the data analysis approach adopted. 99% concentrations were in the range 0.31 to 1.44 µg/m³. The difference between upwind and downwind sampling locations was small at all 4 facilities, with no detectable change on 78% of days. Maximum background RCS concentrations were in the range 0.56 to 2.10 µg/m³ (averages in the order of 0.02 to 0.3 µg/m³). The study concluded that the measured RCS concentrations adjacent to the facilities is within the background range.

Air monitoring was undertaken at and in the vicinity of 7 construction sites in the UK to estimate inadvertent exposures to RCS as a result of the activities (Stacey, Thorpe & Roberts 2011). In total, 48 samples were collected from construction sites with 11 air samples collected from adjacent areas occupied by the community. The sites assessed included demolition, block cutting, road building and general construction activities. The sampling reported evidence of RCS transport from the construction sites to the adjacent public areas, with similar crystalline components reported in both types of samples. RCS concentrations were generally reported to be low for all sites with the exception of several samples from block cutting and demolition activities which reported maximum RCS concentrations of 11.9 µg/m³. RCS concentrations in urban area air in the range 0.08 to 0.44 µg/m³.

Air monitoring was undertaken in January to April 2018 in the Yaldhurst district, New Zealand, where quarrying activity is undertaken and where residential dwellings are located just over 500 m away from the quarried areas.²² Air monitoring was undertaken by Environment Canterbury, Christchurch City Council and the Canterbury District Health Board in response to community concerns about potential health effects from dust coming from the quarries in this area. The intent of the monitoring program was to gather sufficient data to determine if levels of dust and RCS from quarrying activities poses a long-term health risk to residents nearby to the quarries. The monitoring included a long-term monitoring program at 7 fixed locations as well as in-home monitoring for 8 residents (including 1 control resident who did not live in the vicinity of any quarrying activity). A community health air guideline of 3 $\mu\text{g}/\text{m}^3$ was adopted for RCS. Concentrations of RCS in dust from the fixed and in-home monitoring were above background levels at some locations but not considered to be of concern for human health. The maximum concentration of RCS reported in dust was 1.7 $\mu\text{g}/\text{m}^3$. It was identified that nuisance dust was an issue at some times.

Information is also available from 4 sites in Australia where monitoring for RCS has been undertaken in the vicinity of quarrying or tunnelling sites in response to community concern. These studies are discussed below.

Darlington Range, Queensland

Information is available from air sampling undertaken by the Queensland Government Department of Science, Information Technology and Innovation, to investigate air quality in the residential suburbs bordering the 6 large hard rock quarries in Ormeau and Yatala in South-East Queensland (DSITI 2017). At Yatala, monitoring was undertaken at a private residence approximately 1.6 km north of the nearest quarry and 150 m from the road used by trucks to transport quarry products. At Ormeau, monitoring was undertaken at a private residence approximately 500 m east of the nearest quarry. Weekly sampling for $\text{PM}_{2.5}$ samples for crystalline silica analysis was undertaken at both sites between September 2015 and November 2016.

The 7-day crystalline silica concentration reported in the $\text{PM}_{2.5}$ fraction was compared to the OEHHA (2005) Reference Exposure Level (REL; refer to **Table A1**) of 3 $\mu\text{g}/\text{m}^3$. Maximum 7-day crystalline silica concentrations at both sites were reported to be low, with concentrations of 0.07 $\mu\text{g}/\text{m}^3$ reported at Ormeau and concentrations of 0.13 $\mu\text{g}/\text{m}^3$ reported at Yatala. The average 7-day concentration was 0.03 to 0.04 $\mu\text{g}/\text{m}^3$, with crystalline silica above the limit of reporting only measured in 8 to 14% of samples. On this basis, it was concluded that dust emissions from local quarries contain very low concentrations of RCS that are not expected to result in adverse health impacts. This is noted in the report to be like another site investigated by the Department at Mount Cotton.

Continuous monitoring was also undertaken for $\text{PM}_{2.5}$ and PM_{10} , with the following average concentrations reported (PM_{10} samples were not analysed for crystalline silica):

- Yatala: $\text{PM}_{2.5}$ of 4.5 to 5 $\mu\text{g}/\text{m}^3$ and PM_{10} of 12 $\mu\text{g}/\text{m}^3$; and
- Ormeau: $\text{PM}_{2.5}$ of 4.3 to 5 $\mu\text{g}/\text{m}^3$ and PM_{10} of 18.3 $\mu\text{g}/\text{m}^3$.

²² <https://www.ecan.govt.nz/get-involved/news-and-events/2017/working-together-to-resolve-quarry-dust-issues>

Brisbane, Queensland

Monitoring for RCS was undertaken by the Queensland Government Air Quality Sciences Unit of the Department of Environment and Resource Management to investigate potential health effects from the inhalation of silica dust from the Airport Link/Northern Busway construction works at Lutwyche, Brisbane, Queensland (DERM undated). The monitoring was undertaken in response to community concerns in relation to dust emanating from the construction works. The report indicates that RCS is a potential component of airborne dust from the construction works due to the need to tunnel through granite, quartz and sandstone.

The monitoring measured concentrations of crystalline silica in the PM₁₀ and PM_{2.5} fractions at 2 sites in Lutwyche, including at a private residence adjacent to the southern end of the construction works and a church to the east of the works area. Monitoring was undertaken over a 7-day period on 16 occasions between April and August 2011. The average overall 7-day crystalline silica concentration was 0.57 to 1.43 µg/m³ in the PM₁₀ fraction and 0.57 to 1.21 µg/m³ in the PM_{2.5} fraction, with the following concentration range reported:

- 7-day PM₁₀ fraction site 1: 0.22 to 1 µg/m³;
- 7-day P_{2.5} fraction site 1: 0.21 to 0.97 µg/m³;
- 7-day PM₁₀ fraction site 2: 0.5 to 3.72 µg/m³; and
- 7-day PM_{2.5} fraction site 2: 0.21 to 2.17 µg/m³.

The difference in concentrations at site 1 and site 2 was concluded to be due to wind, which favoured the migration of dust towards site 2. Measurements at site 2 were concluded likely to be representative of worst-case weather conditions. Significant effects due to rainfall were not noted.

Consistent with the DSITI (2017) assessment, RCS concentrations reported in dust were compared to the OEHHHA (2005) REL of 3 µg/m³. This guideline was adopted as there are no Queensland community air guidelines for RCS, however the report notes that the OEHHHA guideline has been adopted by Victoria. The guideline was compared to the report PM_{2.5} and PM₁₀ concentrations as sampling equipment is not available to measure RCS concentrations of 3 µg/m³ or less. Given the similarity of reported PM_{2.5} and PM₁₀ concentrations at both sites, and that overall average concentrations of both size fractions were below the adopted guideline, it was concluded that adverse health effects within the community from RCS from the works were unlikely.

Hunter Valley, NSW

An air quality study was undertaken at 2 locations in the Hunter Valley airshed in NSW in the vicinity of operating open-cut coal mines (Morrison & Nelson 2011). This study reported RCS concentrations of 0.5 to 1.8 µg/m³ for the PM₄ fraction and 0.2 to 1.4 µg/m³ for the PM_{2.5} fraction. Given that these concentrations were below the OEHHHA (2005) guideline of 3 µg/m³ it was concluded that adjacent populations were not at risk of silica induced disease.

Oxenford, Queensland

Air monitoring for RCS was undertaken at the request of the Queensland Government in response to community concerns about potential health impacts from dust in Oxenford²³. Data from quarry operators in the areas was provided and reviewed, with no concerns in relation to human health identified. A 14-month (April 2020 to May 2021) air quality monitoring project was also undertaken, which included monitoring for RCS in dust. The measurement site was located approximately 500 m west of the quarry. A community health air guideline of 3 µg/m³ was adopted for RCS in PM_{2.5}. The results of the monitoring showed no evidence that dust emissions from the quarry were a significant contributor to ambient RCS in PM_{2.5}. No exceedances of the relevant objectives for protection of human health were reported, with RCS not detected throughout most of the monitoring period except for two weekly sampling periods when region-wide dust events brought dust from inland Australia across Southeast Queensland which resulted in very low concentrations of RCS in the samples. The average RCS concentration was 0.02 µg/m³.

A7 Background exposures

ATSDR (2019) indicates that silica containing airborne dust is present in the environment as a result of the widespread natural occurrence and use of silica-containing products and materials. Local meteorological conditions can cause elevated concentrations of silica in dust, most notably in areas around recent volcanic eruptions and deserts (desert dust consists of fine particles, <10 µm, with a higher percentage of quartz). Monitoring has indicated that remote continental air contains a background dust concentration of 0.04 mg/m³, or which ≥10% (i.e. ≥0.004 mg/m³) may be crystalline silica. TCEQ (2009) indicates that the average ambient RCS is 1.9 µg/m³, with a range of 0.3 to 5 µg/m³. This is slightly lower than other estimates for the USA which indicate average quartz levels in metropolitan areas of 1.1 to 8 µg/m³ (average of 3.2 µg/m³) (Bhagia 2012).

ATSDR (2019) provides a summary of studies that have measured ambient RCS concentrations in urban environments, including those adjacent to silica industries. The available data is summarised in **Table A2**.

²³ <https://www.qld.gov.au/environment/management/monitoring/air/air-programs/other-dust-and-particulates/oxenford>

Table A2: Summary of measured RCS or quartz concentrations in urban environments¹

Location	Concentration ($\mu\text{g}/\text{m}^3$)	Comments
Background Locations		
USA	0.9 to 8	24-hour ambient concentration of RCS sourced from 2.5 to 5 μm quartz in urban areas, as measured at 22 sites in several different states.
California, USA (WDNR 2010)	1.2 to 3.5	Silica concentration in PM_{10} fraction from 12 samples collected in urban areas.
	0 to 1.4	Silica concentration in PM_{10} fraction from 16 samples collected in rural areas.
	0 to 1.2	Silica concentration in PM_{10} fraction from 18 samples collected in remote background areas.
California, USA (Bhagia 2012)	1.1 to 1.3	Based on reported PM_{10} concentrations of 18.2 and 18.9 $\mu\text{g}/\text{m}^3$ with a 6-7% silica content.
Rome, Italy	0.25 to 2.9	As total PM_{10} with a mean diameter range of 0.3 to 10.5 μm where >87% of particles had a diameter of <2.5 μm . Silica concentrations in dust thought to be from the Sahara Desert as carried to Mediterranean Europe via the Southern Winds.
Tokyo, Japan	≤ 34	Concentration of quartz in air samples (no information on silica concentration or potential sources).
Locations Adjacent to Silica Industries		
California, USA	26 to 97	Airborne quartz concentration up to 750 m downwind a sand and gravel facility. PM_{10} concentrations were in the range 26 to 1,026 $\mu\text{g}/\text{m}^3$.
	4 to 16	Background (upwind) quartz readings.
California, USA	<0.3 to 2.8	RCS (as PM_4) concentrations up and downwind of a quarry and processing plant. The 8-hour working shift PM_{10} RCS concentration was 1 to 19 $\mu\text{g}/\text{m}^3$. This study was sponsored by the US National Stone, Sand & Gravel Association with samples collected down wind of 4 crushing plants processing high-quartz-context rock.
Minnesota, USA	<1 to 7	RCS (as PM_4) concentrations in ambient air near industrial sand mining, processing and transport sites.
Minnesota, USA (Richards & Brozell 2015)	0.4 to 1.3	Maximum RCS concentrations adjacent to 2 frac sand operations.
Gansu Province, China	$\leq 5,720$	Dust, comprising fine particles of <5 μm , from sandy areas during the windy season. Dust concentration was 8,350 to 22,000 $\mu\text{g}/\text{m}^3$ of which 15 to 26% was free silica.
India	41 to 57	PM_{10} quartz concentration near an industrial slate pencil site.
	3.5	PM_{10} quartz concentration at a control site for the industrial slate pencil site (5 km away)
India	31 to 67	Based on average ambient air $\text{PM}_{2.5}$ at two villages near stone crushing sites and a silica content of up to 24%.
	120 to 156	Based on average ambient air PM_4 at two villages near stone crushing sites and a silica content of up to 24%.
	110 to 185	Based on average ambient air PM_{10} at two villages near stone crushing sites and a silica content of up to 24%.
	1,082 to 1,956	Based on ambient air PM_4 at stone crushing site and a silica content of up to 24%.
India (Bhagia 2012)	15.3	Average concentrations of crystalline silica (quartz) at 4 sites in the vicinity of agate industry. Control locations reported a concentration of 3 $\mu\text{g}/\text{m}^3$.
South Africa (Andraos, Utembe & Gulumian 2018)	17.4 to 34.9	PM_4 via personal monitoring approximately 0.2 to 7 km away from a tailing storage facility (8 sampling locations).

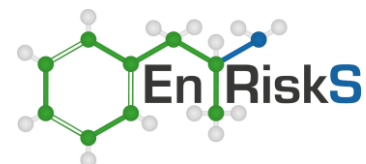
Notes:

¹ = Ref. ATSDR (2019) unless otherwise noted.



Review of the above data indicates that where there are specific industries that generated RCS, and these are unmanaged (in terms of dust), levels of RCS in air adjacent to these facilities is significantly elevated (reference data for China and India). Levels adjacent to such industries are lower where dust generation is better managed (such as a number of sites in the US).

Where there are no specific RCS industries present background levels are lower. The average ambient RCS value of $1.9 \mu\text{g}/\text{m}^3$ from TCEQ (2009) is considered a reasonable average that reflects an annual average exposure. This value is higher than the background levels reported in the Darlington Range in Queensland and similar to average values reported in Brisbane and the Hunter Valley, noting that all these sites are near RCS generating industries. Hence a typical background level of RCS in air of $1.9 \mu\text{g}/\text{m}^3$, which is assumed to be as $\text{PM}_{2.5}$, is conservative for many areas.



Appendix B Scope Geo Report

PETROGRAPHIC REPORT

Microscopic analysis was undertaken in transmitted, polarized, and normalized light on a prepared thin section from a fine aggregate sample. The composition of the thin section herein is based on a widely spaced 200-point count. Account has been taken of ASTM C295.

Examined By:



T.F.D.Spring

BAppSc, MAppSc, MAIG

Reviewed By:



K.E.Spring

BSc, MAppSc

Prepared For: GSG Laboratories (Tamworth)

Client Address: 82 Plain St, Tamworth NSW

Project #: GSNS-TAM-25-1392

Report Number:

Sg2601037pet

Work Request #:

4314

Report Date / No. Pages:

February 2026 / 5

SAMPLE DETAILS

Sample Number: T4612A

Lab ID:

Sg2601037

Sample Type: Fine Crushed Rock

Date Sampled:

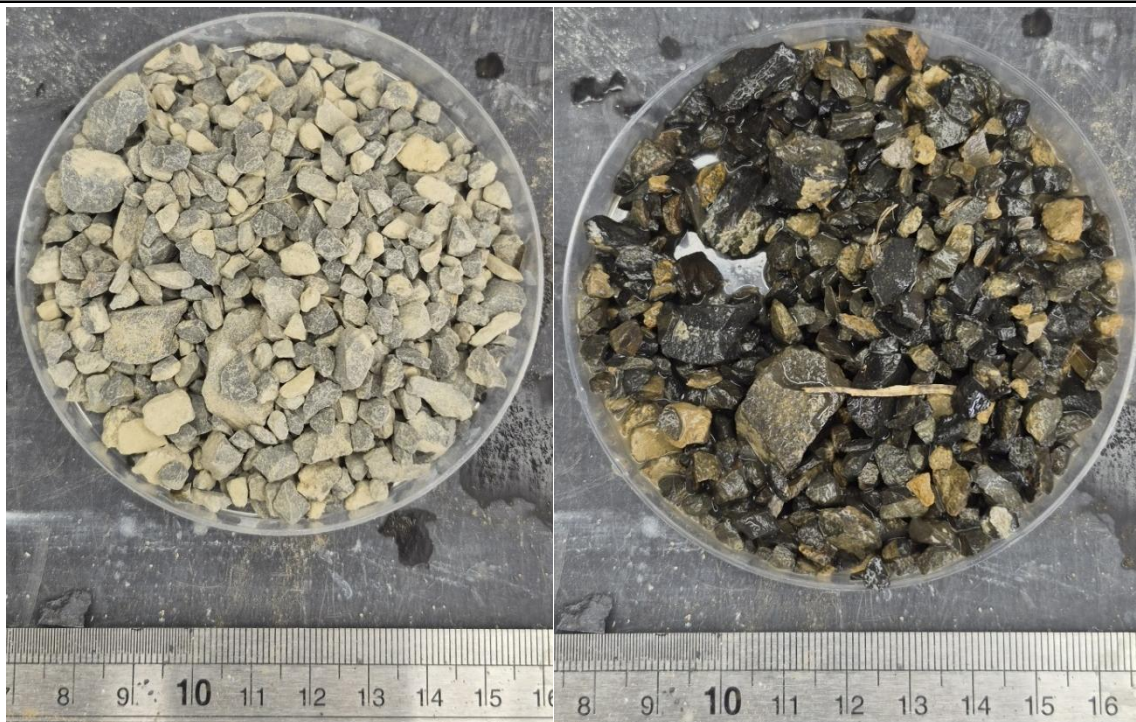
05/12/2025

Date Sent: 13/01/2026

Date Received:

15/01/2026

Work Requested: Petrographic analysis

DESCRIPTION

The supplied fine aggregate samples comprised apparently moderately weathered, grey, reddish grey and pale grey, very fine-grained sedimentary rock with carbonaceous wisps throughout. Some fragments can be readily scratched with a steel tool and are moderately robust and essentially soft while minor amounts are more robust and can only be lightly but easily scratched with a steel tool.

INTERPRETATION and RECOMMENDATIONS

Identification: **Mudstone** (sedimentary rock)

The supplied material contained 56.0% durable components, 6.5% moderately durable carbonate, 37.5% soft, weak and deleterious components and <0.5% pores. It considered to be **moderately hard, moderately robust** and therefore in a **moderately-durable** condition.

Suitability:

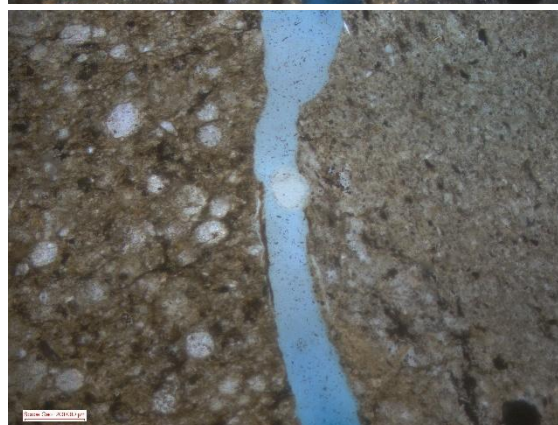
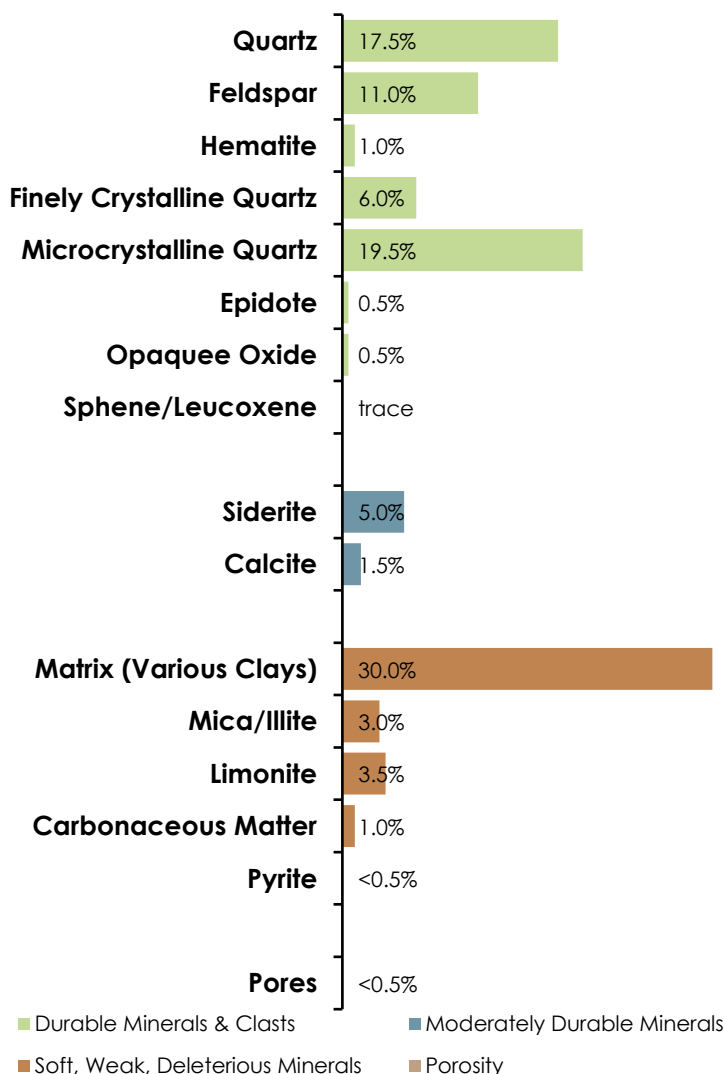
Based on petrographic assessment alone, the material of the type represented in the supplied sample is predicted to be:

- **Potentially adequate for use as construction material**, subject to the preposed use of the material. The sample contains a mixture of soft weak fragments and more durable fragments, targeted extraction of more durable material may result in a better product.

Free Silica Content:

43.0% present as sand sized grains (17.5%) and locked within various lithic clasts of finely crystallized quartz (6.0%) and microcrystalline quartz locked within the matrix intermingled with clays (19.5%).

EXAMINATION FINDINGS



Micrograph shows the rare quartz and feldspar grains in a dark stained matrix, note the radiolarian in the fragment on the left. Mag: 5x, xpl (top), ppl (bottom).

EXAMINATION FINDINGS

Comments:

The supplied fine aggregate sample is seen to consist of poorly sorted clasts within an intermingled clay cemented matrix. Examination findings detail the durable components of the fine aggregates amounted to 56.0%, with a further 6.5% moderately durable carbonate (siderite and calcite) with soft, weak (non-durable) and deleterious components amounted to 37.5% along with rare porosity amounting to <0.5%. The rare, suspended clasts are generally subrounded, typically between 0.05 mm and 0.15 mm comprising of quartz and feldspar and rare lithics in the form of quartzite.

The material is dominated by non-durable components comprising mostly a matrix of intermingled clay along with limonite and rare heavily argillized clasts. Some of the matrix appeared to have been overprinted by sideritic carbonate, giving the rock some added strength. In other fragments the matrix appears to have been replaced by very fine microcrystalline quartz also giving the rock some added strength. Many of the fragments contain radiolarian fossils that have been replaced with finely crystalline quartz. Minor secondary iron oxides, pyritic nodules and carbonaceous matter were also observed. Minor detrital muscovite was also observed within the clay matrix. Fine veins of calcite and limonite are noted.

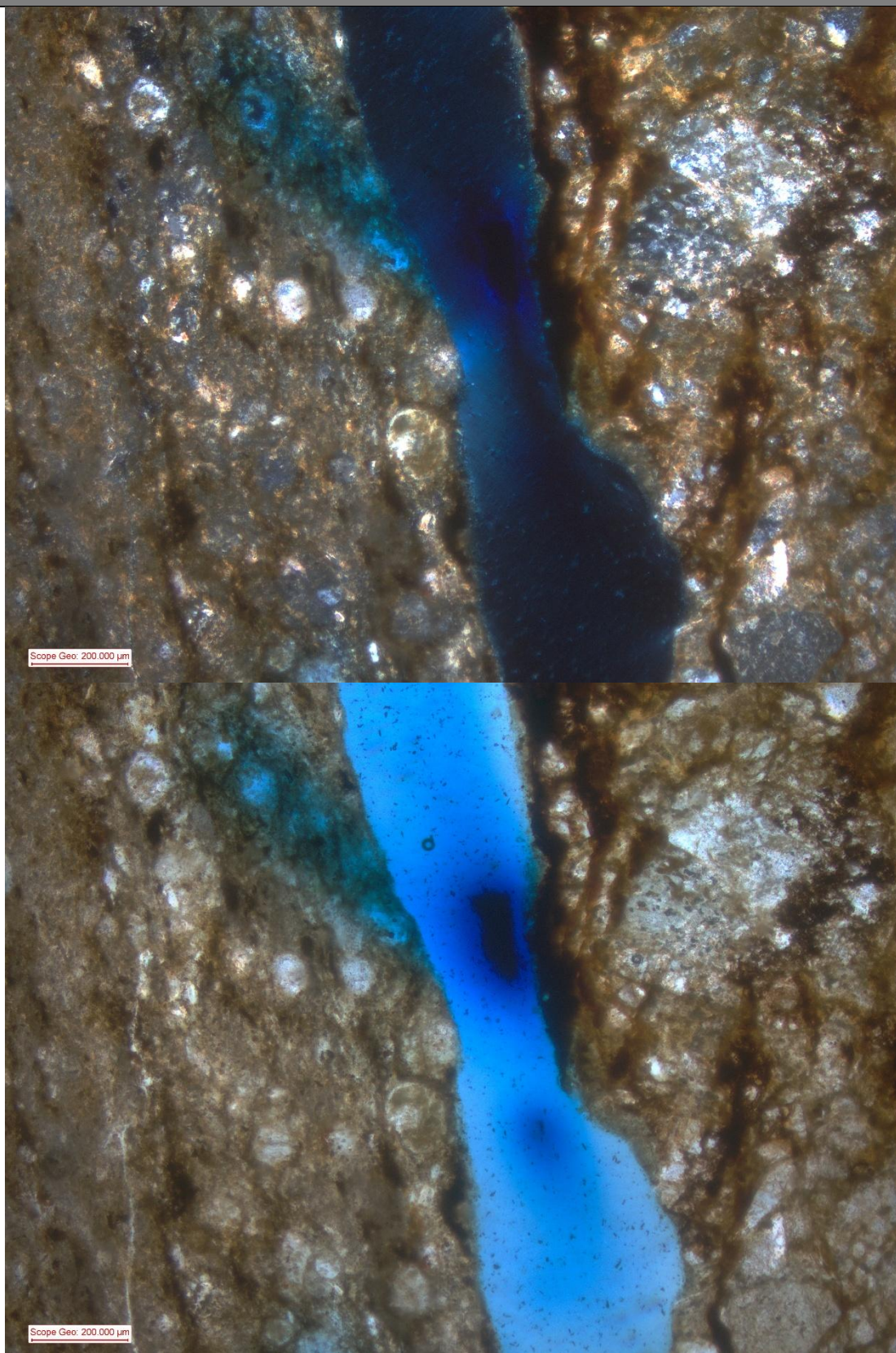
A few fragments are noted to be muddy sandstones with some larger feldspar and minor quartz grains in a clay matrix.

IMAGES



Micrograph taken in cross (top) and plane (bottom) polarized light, at low magnification. The image shows two fragments on the left are a very fine mudstone with rare very fine clasts of quartz and radiolarian infilled with microcrystalline quartz within a clay cemented matrix. The fragment on the right is more coarse grain sandstone that has been largely altered to clay forming a muddy sandstone.

IMAGES



Micrograph taken in cross (top) and plane (bottom) polarized light, at low magnification. The image shows two fragments on the left are a very fine mudstone with rare very fine clasts of quartz and radiolarian infilled with microcrystalline quartz within a clay cemented matrix. The fragment on the right is more coarse grain sandstone that has been largely altered to clay forming a muddy sandstone.